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WROUGHT-IRON CEMENT-LINED WATER PIPE.

BY LEONARD METCALF,* CIVIL ENGINEER.

[*Read December 9, 1908.*]

INTRODUCTION.

In the course of the recent water-works valuation suit at Portland, Me., in which the plants of the Portland Water Company, Standish Water and Construction Company, Gorham Water Company, and the Foreside Water Company were appraised, the writer had occasion to look up experience in New England with wrought-iron cement-lined water pipe. A search of the files of current engineering journals developed some articles of interest, referred to in the bibliography appended to this paper, and led to the sending of an assistant, Mr. William L. Butcher, a member of this Association, to interview the superintendents of several of the New England plants upon their experiences with the wrought-iron cement-lined water pipes in their works. The data thus acquired, with certain observations and deductions by the writer, have been brought together in this form in the hope of eliciting a general discussion upon the merits and demerits of wrought-iron cement-lined pipe, by members of this Association, many of whom have had personal experience with it.

TYPE OF CONSTRUCTION.

Two general methods of building wrought-iron cement-lined pipe have been used in this country: the first, known locally, perhaps, as the Goodhue & Birnie pipe; the second, what is known as the Phipps patent.

The Goodhue & Birnie pipe was generally made by riveting up

* Of Metcalf & Eddy, consulting engineers, Boston, Mass.

sheets of wrought iron, single riveted with cold rivets, without any attempt to make the joints watertight, and lining this wrought-iron shell with from $\frac{3}{4}$ inch to 1 inch of neat Rosendale cement, or cement mortar mixed one part of cement to one part of sand. This work was generally done in a central plant, or at different points along the pipe line, from which the pipe was carried to the trench, there imbedded in Rosendale cement mortar laid along the bottom of the trench, and then covered over the sides and top with a $\frac{3}{4}$-inch to 1-inch layer or casing of Rosendale cement mortar plastered on with rubber gloves or trowel in the hands of the pipe maker. The trench was generally backfilled immediately or shortly after laying the pipe.

The pipes were made in lengths of 9 feet, and the joints between the pipes were made by means of a sleeve of wrought iron with inner and outer casing of cement, or by making the pipe tapering so that the end of one pipe was fitted into the end of the next. In the larger mains the joints were often plastered on the inside after laying; in the smaller ones, this was, of course, not attempted.

The Phipps patent pipe was generally made and coated without as well as within with a $\frac{3}{4}$-inch to 1-inch layer of cement or cement mortar, the outer coating being held in place by a thin sheet of wrought iron which subsequently rusted out in the trench. This outer sheet was of distinct advantage, however, as a protection to the outer cement coating in the handling and laying of the pipe.

In a few cases cast-iron bells and spigots have been riveted to the wrought-iron sheets before making the pipe, and the joints have then been made in the ordinary manner with lead tightly calked in place or by the use of cement mortar.

More recently, under the Phipps patent, a type of cast-iron ring has been developed which is driven home in each end of the pipe, — one of the rings being a female ring, the other a male ring, — thus more rigidly holding the end of the pipe and preventing injury to it in transportation and laying, and incidentally making more convenient the placing of the outer cement coating of the pipe, which is made of grout poured into the mold between the inner and outer sheets, with the pipe standing on end. The joint between pipes is made finally by the use of a sleeve as heretofore.

So far as the writer is aware, no cast-iron joint has thus far been developed which has proven thoroughly satisfactory and advantageous from the standpoint of economy.

It is perhaps worthy of note that while blue annealed *wrought-iron* sheets imported from England were used in many of the early installations, in making the later ones steel has been substituted at some saving in cost, though not in durability.

EARLY HISTORY.

A glimpse of the early history or experience with wrought-iron cement-lined water pipe is given in the report of the well-known engineer, Mr. Phineas Ball, of Worcester, Mass., to the city of Springfield, to be found in the report of the Board of Water Commissioners to the City Council for the year 1876, which is quoted below at some length:

Extract from Report of Phineas Ball, dated at Springfield, Mass., January 15, 1876.

"Of Wrought Iron and Cement-Lined Pipe in General."

"There is always in every community a certain number of intelligent citizens who entertain honest doubts as to the utility of using this kind of pipe. In the minds of many of the citizens of the city, this doubt has existed and still exists. Under various forms during the last two and a half years this want of confidence has been freely expressed by many. After an experience of twelve years in laying and watching wrought-iron and cement-lined pipe, and having examined many samples of pipe removed for various causes, and after examining defects that have appeared under a variety of conditions, and made many inquiries into the immediate cause leading to individual defects, and having consulted with those of large experience with this kind of pipe, your indulgence is claimed to express upon this subject a more direct and a more explicit opinion than I have ever heretofore given in any previous paper or report.

"The durability and permanent usefulness of wrought-iron cement-lined pipe rest upon two principles:

"*First.* Wrought iron possesses the property of sustaining a tensile strain from three to four times greater than cast iron in the same sectional area.

"Ordinary pig-iron, of which cast-iron water pipes are mostly made, will bear a tensile strain from 13 000 to 22 000 pounds per square inch.

"Messrs. Alan Wood & Co., the makers of the iron used upon your water works, furnished a series of tests of samples of iron manufactured by them of the same brand as that which was used in making the pipe, which gave an average of 55 000 pounds per square inch, the tests ranging from 46 000 to 71 000 pounds to the square inch.

"Cast iron is crystalline in its structure, and in casting even the best is 'liable to air bubbles and other defects, which render its tensile strength very unreliable.' Wrought iron is not subject to this peculiarity and in all places where this special property is most needed, wrought iron is now nearly universally used. In a water main the tensile strength is the one that is constantly in use when a pipe is under pressure, the same as in a steam boiler, and is the property that any material of which a water pipe is made must possess in a very high degree in order to be useful for this purpose. Cast iron lacking this high tensile resistance when used for a water pipe, the deficiency is made up in extra thickness of the shell. And further, as experience has abundantly proved, cast iron when used for pipe is subject to decay from oxidation, to provide for which decay the usual practice is to add to the necessary thickness needed to stand the pressure from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch for what is called the 'life of the pipe.' Therefore, in the use of cast-iron pipe, nearly one-half of the metal employed is taken to provide for contingencies that are over and above the requirements for the strength. In this respect wrought iron has a decided advantage over cast iron. The uniformly reliable tensile strength of wrought iron is well known, which property enables a pipe of the requisite strength to be made of it with a very small amount of materials as compared with cast iron.

"The *second* principle is that of the protective power of cement to prevent the oxidation of iron when used underground. In numerous instances this protection has been proved by actual experiment to be singularly effective and complete. In removing small sections of lines of water pipe that have been in use six, eight, ten or twenty years, a great number of lengths will be found to be entirely free from all rust and in such a state of preservation that there seems no reason why such pipe should not endure for centuries. If what is seen as a reliable result upon numbers of pipes removed could be said of it as a whole, its trustworthiness as a permanent water conductor would be assured beyond all question. That the preservative effects of the cement is complete on some pieces and of parts of others and not upon all pieces and every portion of the pipe to which it is applied is the enigma. To make it universally protective where at present it appears only locally so, is the problem presented for solution. To a consideration of this question the attention is directed.

" In the usual mode of making and laying this kind of pipe, my experience has forced upon me the conclusion that there are *two prominent causes which have constantly operated to defeat the protective property of the cement as applied to the iron.* The *first* lies in the fact that the *iron shells have not been made watertight previous to the application of the cement.* Nor is this defect completely remedied either in the manner of lining or laying, as is commonly supposed.

" The *second is, the use of sand with the cement,* as in case of ordinary mortar.

" In the making of the shells, usually, no pretense has been made of making riveted joints watertight. To secure a watertight joint along the riveted laps, reliance has been had entirely upon the cement lining to fill up and make proof against the exit of water any space left open in the riveting. That many pieces are thus made watertight there is ample evidence. But that the vast majority of pipes are not watertight at the riveted laps is too painfully evident from the inspection of any considerable number of pipes taken up that have been in use a number of years. That leaks so large as to require to be ' mended ' do occur upon the riveted laps is well known to all experienced in the care of this kind of pipe. This form of ' leak ' is not as common as the one at the joint, but still frequent enough to reveal the fact that in this respect it is a defect that needs attention and the application of a remedy. Where one leak of this kind appears on the surface, many more, very small, indeed, occur, only the result of a slight oozing through the cement lining, but sufficient to lift the covering from the outside of the iron and thus commence and continue the oxidation of the iron, until the pipe is ruined.

" My experience has convinced me that leaks of this small character are far more common and numerous upon laps than at joints. That, as a rule, if a joint leaks, sooner or later it will make its appearance at the surface of the ground.

" The second point, that of the use of sand with cement, making it into mortar the same as that used for ordinary stone and brick work, I deem important. It is cement which possesses the peculiar property of preventing oxidation and not sand. Sand dilutes the cement and makes the resulting mass less adhesive when applied to the iron and decreases the tensile strength of the hardened mortar.

" The original patent for this kind of pipe was granted to Jonathan Ball, of New York City, dated December 15, 1843. The claims in the original patent are as follows, to wit, ' What I claim as my invention is the application of hydraulic cement or water cement as a coating upon the interior surface of metallic water pipes to prevent the corrosion and oxidation of the metals of which

the pipes are composed. Also the means by which it is accomplished, as set forth.'

"The original patent was reissued September 15, 1857. In this reissue the word 'cement' is used fourteen times; 'hydraulic cement,' four times, and 'Roman cement,' once; while the word 'sand' does not occur and there is no reference whatever to its use in connection with cement by any form of expression or phraseology used in the document. In practice, however, singularly enough, from the earliest application of the device, the cement was always used mixed with sand in the same manner as in mason work. The earliest recorded line of pipe laid under this patent is one mentioned in the circular of the Patent Water and Gas-Pipe Company, under the date of 1875, by whom it was introduced as being laid in Jersey City in 1845, and referred to in a certificate of Samuel McElery as having been examined by him March 20, 1867. The next oldest line mentioned was laid at Saratoga in 1847, since which time the pipe has been laid in many cities and towns. From time to time various defects appeared, mostly in the destruction of the iron of the pipe by rust. Some of these appeared quite anomalous because no satisfactory reason could be given for their occurrence. For these defects and anomalies the common explanation given was that the cement mortar, meaning the cement and sand, was not properly mixed, or in some cases loam or clay would accidentally get mixed with the mortar and form a very porous mortar, or clay or loam coming in contact with the pipe before the cement covering was applied, by all of which means oxidation was induced. After very diligent inquiry in 1873 and previously of many persons of much experience with this kind of pipe, want of uniformity of mixing the mortar seemed to be the unanimous opinion as the prime cause of all, or nearly all, of the defects observed to that time. On your works the defects of imperfect mixing was remedied, where any sand has been used, by mixing the mortar by machinery.

"An examination of the pipes removed on your works from Chestnut Street and one or two other sections in 1874, and from a hint in a letter from Hon. F. T. Stanley, of New Britain, Conn., dated May 20, 1874, to the Water Commissioners of Fitchburg, in which occurred the following language: 'It is evident to us that the sand that was used here has had more to do with their failure than any other cause, it having more or less admixture of loam,' caused me to investigate the matter anew, and from a different standpoint.

"The use of wrought iron in the construction of bridges, buildings, roofs, and ships has become so common that the subject of its preservation from oxidation has become one of general interest. The causes of rust or oxidation are general; the prevention may

require special means adapted to the kind of structure under treatment. Inquiries into the active causes producing oxidation the most rapidly have been and are still being prosecuted with care and by the aid of science.

" In a paper read by Prof. E. Crace Calvert, before the Literary and Philosophical Society of London, and quoted by *Van Nostrand's Engineering Magazine* for 1871, Vol. IV, page 522, after giving in detail his experiments, he states that ' these series of experiments substantiate the interesting fact observed, — that carbonic acid promotes oxidation '; in the course of establishing which fact he made another series of experiments extending over a period of two years in order to ' throw some light on the curious fact, first published by Berzelius, that caustic alkalies prevent the oxidation of iron.' The main fact substantiated by this series of experiments was ' that the carbonates and bicarbonates of alkalies possess the same property as their hydrates,' that of preventing oxidation. In an article quoted by the above magazine from the *Builder* on " The Preservation and Purity of Iron," Vol. III, page 527, the writer arrives at the conclusion that ' the presence of carbonic acid is necessary for the production of rust,' and mentions the interesting fact of the demolition of the Wriothesly Street bridge on the London and Birmingham extension railway, a bridge which was built in 1835, composed of iron and brick work, that at the time of its being taken down ' it was found to be extremely difficult to separate the brickwork from the girders. It was as easy, or more so, to break the bricks themselves. But when the separation was effected, it was found that this unusual adhesion was caused by the entire absence of rust.' These girders were set in brickwork in Roman cement. The phenomenon of the close adhesion of the cement to the iron is frequently seen in the case of pipe underground, where, on removing the cement, it will be found to cleave off not clean from the iron, but leaving a film of cement on the surface of the iron, and on removing this film, the iron will be found perfect on the parts where this intimate adhesion occurs.

" Another consideration having an immediate bearing upon this subject is the fact established by recent investigations upon the composition of the underground atmosphere. That all soils are porous is a well-known and well-established fact. It has been well ascertained that the pores in the soil, when not filled with water, hold in their spaces air, and further recent investigations show that the composition of underground air in one particular is very different from that of ordinary air. The difference is in the large amount of carbonic acid found in the ground air over that in the atmospheric.

" This subject, in our state, was investigated by Prof. William

R. Nichols, of the Massachusetts Institute of Technology at Boston, during the year 1874. The result of these researches was published in the annual report of the State Board of Health for 1875. The facts here quoted are taken from that report. The normal 'amount of carbonic acid in the outer air may be taken as generally lying between 0.30 and 0.45 part in 1 000.' In the filled land in the Back Bay, in Boston, at a depth of 6 feet below the surface, on August 20, 1874, Professor Nichols found 20.71 parts of carbonic acid in 1 000, or between 46 and 69 times the amount in atmospheric air. This quantity is the largest found at any one time. The average of 31 determinations is 8.83 parts in 1 000, or between 19 and 29 times the amount in the outer air. The lowest amount found was January 5, 1875, when it was only 2.45 parts in 1 000, or between 5 and 8 times the amount in common air. To insure the protection of the iron from the influence of carbonic acid, the coating must be impervious or of such chemical character as to neutralize its destructive agency. The cement may act in both ways; first, by hardening, form an impervious coating, or second, by absorbing the carbonic acid, converting the caustic lime in the cement into a carbonate, or reconverting the mass into elements analogous to those of the natural rock of which the cement was made.

"In testing cement its tensile strength is always found to be the greatest when used pure without an admixture of sand. Sand dilutes the mixture; the more sand, the less tensile strain will it bear, showing that, in a mass of hardened pure cement mortar the particles are more closely united, each to each, than is the case when sand is used.

"One fact is quite noticeable in repairing and removing lines of cement-lined pipes, and that is the very nearly complete preservation of the sheet iron of which the sleeves are made at the joints and the iron of the pipe itself under the joint when perfectly filled. In May, 1870, a portion of the 16-inch main which supplied the city of Worcester was lowered. The number of lengths removed was 164; the number of sleeves, 165. The area of the two surfaces of each sleeve was 6.8 square feet. The total area in the 165 was 1 122 square feet. Upon this entire area scarcely a speck of rust could be found, and the same was to be observed on the pipes under the sleeves. This pipe had been laid six years. The preservation of this iron was partly due to the richer mortar used in filling the sleeve. For a few years past sand has been entirely discarded in 'joint mortar' in laying the pipe. In answer to many inquiries of persons who have the care of works where this kind of pipe is in use, whether rust on and under 'sleeves' is common, I have always been informed that it is very rare indeed to find a sleeve rusted out, or on which rust appears.

"The conclusions, therefore, at present reached may be summarized as follows:

"*First.* That wrought iron as a material of which to make water pipes is much more reliable than cast, with a great economy in the employment of materials.

"*Second.* That the sheet-iron shells should be made watertight before lining with or laying in cement.

"*Third.* That in applying the cement no admixture of sand should be allowed.

"*Fourth.* That owing to the economy with which this pipe can be laid, generally, as compared with cast iron, especially for large sizes, if laid with watertight shells and in pure cement, its use will repay the investment.

"Present experience has brought me to the foregoing conclusions. They are not put forth as final. Further evidence upon the behavior of pipe laid upon the method indicated might lead me to reject the pipe altogether, but until that adverse evidence is received my opinion is that there are many localities in which it may be used for the public benefit. The pipe has many good qualities in its favor, and by a careful study of the facts which relate to its preservation the practice of the principles upon which its permanence rests may be so perfected that it may be as safe to lay this kind of pipe as cast iron. In concluding this subject, I will add that all of the wrought-iron pipe laid on the works this year has been lined and covered with pure cement, without sand, and that more than half of that laid last year was first covered with a layer of about one-quarter inch in thickness before the sand mortar was put on."

In the year 1888 a joint special committee of the City Council of Springfield charged with the investigation "of the problem of how best and most economically to lay a new main from Ludlow to obtain an increased water supply" sent out circular letters to many towns and cities in New England in which cement-lined pipe had been used, asking for information of their experience with it. The result of this inquiry was summarized in an article in *Engineering News*, in Vol. XXI, January to June, 1889.

Extract from "Engineering News," Vol. XXI, 1889.

"A joint special committee of the City Councils of Springfield, Mass., has been chosen to investigate the problem of how best and most economically to lay a new main from Ludlow to obtain an increased water supply. A 24-inch cast-iron main would cost

$225 000, which might be laid to connect with the existing 24-inch cement-lined main. In discussing the question of cast iron *v.* cement-lined pipe, the committee sent to 50 cities and towns a series of questions relating to durability, etc., of cement-lined pipe, and whether or not such pipe was being replaced by cast iron. Forty replies were received and the majority stated that the use of the lined pipe was in disfavor and that it was being rapidly replaced by cast iron. Brooklyn had used cement pipe between 1859 and 1884, but had given it up as unserviceable. Chelsea, Mass., used some such pipe twenty-one years and its condition is fairly good, but cast iron was found to be more reliable and economical. Worcester had a little of this pipe in use for twelve to sixteen years, but the condition is poor, owing to frequent leaks. Hartford, Conn., has 12 miles of cement pipe and has used it twenty-five years but it has been given up as causing more trouble from breaks. Fitchburg, Mass., used such pipe between fourteen and seventeen years, but has given it up as a matter of safety and because the repairs cost more than the change to cast iron. Concord, N. H., has cement pipe laid for sixteen years, and as it is in good condition still adheres to it. Brockton reports cement pipe as all right and no leaks.

"In Pittsfield the water commissioners say that cement pipe has been used since 1855 and its condition is good as far as they know. New Bedford officials consider the pipe unreliable. In New Haven the pipe is considered reliable and no change is contemplated. Meriden, however, sings a different tune. There the cement pipe has been used since 1869 and its condition is very poor. It cannot stand a pressure of more than one hundred pounds. Woburn considers that its condition is perfect with a pressure of between 60 and 95 pounds. It has used the pipe fifteen years and does not contemplate a change. Manchester, N. H., has the pipe laid fifteen years ago, but does not want any more because it bursts. The pipe in Salem has been laid twenty years and is considered good, so they are not substituting iron pipe. Cambridge has not laid any for fifteen years and is substituting iron because there is no doubt of its advantages. New London has laid no cement pipe since 1872, and the commissioner says, 'I would on no account lay a large main of cement-lined pipe, and small mains with only those of the best workmanship and material.' Providence considers the pipe treacherous. Experience in Somerville shows that the pipe bursts, there being an average of eighty breaks a year. Portland, after twenty years' experience, has taken all the pipe up because it could not stand the pressure. In Waltham the pipe has been used since 1873, but as it is beginning to rust, no more cement pipe will be laid. Boston has little of this kind of pipe. It is found to rust and burst.

Malden has some laid twenty years ago, and is substituting iron pipe.

" The answers to the questions as to the amount of water used per capita and the annual receipts were not given in all the slips returned. Those which were given, however, are interesting to compare with Springfield's rate per capita per day of 100 gallons, and her receipts of $129 464 last year. The other cities are as follows:

"*Gallons Used per Capita.* Holyoke, 71; Fitchburg, 60; Taunton, 32; Lawrence, 68; Cambridge, 50; Albany, 100; Hudson, 148; South Framingham, 40; New London, 99; New Bedford, 85; New Haven, 112; Meriden, 50; Woburn, 60; Manchester, N. H., 45; Brooklyn, 66; Jersey City, 100; Chelsea, 60; Worcester, 50; Hartford, 50; Providence, 44; Syracuse, 80; Troy, 130; Lowell, 65; Portland, 150; Waltham, 30; Boston, 80; Malden, 65.

"*Annual Receipts from Water Rents.* Northampton, $22 364; Fitchburg, $51 000; Taunton, $39 444; Concord, N. H., $38 441; Newark, N. J., $340 000; Utica, $70 000; Brockton, $26 000; Pittsfield, $25 000; New Bedford, $51 000; New Haven, $210 000; Meriden, $50 000; Woburn, $26 118; Manchester, $80 000; Lawrence, $80 554; Salem, $52 000; Cambridge, $214 000; Albany, $255 900; South Framingham, $12 000; New London, $23 575; Jersey City, $539 227; Chelsea, $70 000; Worcester, $130 000; Hartford, $145 000; Waltham, $41 127; Boston, $1 540 000; Holyoke, $58 954; Malden, $59 877; Providence, $346 731; Syracuse, $77 000; Lowell, $180 000; Somerville, $90 000."

In 1894 Mr. John R. Freeman, then secretary of the Winchester Water Board, presented a report to the town, to be found in the twenty-second annual report of the Winchester Water Board, January, 1895, in which he discussed the question of the advisability of further installation of wrought-iron cement-lined pipe in Winchester, Mass. Mr. Freeman's conclusions were:

"*First.* Cast-iron pipe can now be laid cheaper than cement-lined. Cast-iron pipe of the size mostly used (6-inch) costs in long lines and easy digging, exclusive of gates and hydrants, which are the same in either case, about 55 to 60 cents per foot for material and labor, all laid; while 6-inch cement-coated sheet-iron costs about 65 to 70 cents under same conditions.

"*Second.* Cast-iron pipe is much the stronger. The computed bursting strength of new pipe is about ten times as great for the cast-iron as for the sheet-iron pipe with its riveted longitudinal seam. The cast-iron pipe is eleven times as thick as the wrought-

iron used, and the greater thickness thus more than offsets the brittleness of cast iron.

"The cast-iron, 'Class B,' is all tested at the foundry by a water pressure of 300 pounds per square inch, and will safely stand the water ram and working strains incidental to 100 pounds per square inch working pressure without danger of bursting under fire duty. Sheet-iron pipe as heretofore used could not be trusted under much more than 50 pounds pressure for domestic draft; and even with this pressure there is always a danger that a temporary quick shutting off of hose streams during a fire may burst the mains and instantly render the water service useless. Various cases can be cited where such accidents have happened, and there is consequently among many insurance experts a strong prejudice against cement pipe in a public water supply.

"*Third.* The life of cast-iron pipe is much longer than that of cement-coated sheet iron. The thickness of cast iron used for a 6-inch pipe is 0.5 inch. The thickness used for several years past in Winchester for 6-inch sheet-iron pipe is $\frac{1}{22}$ inch; in other words, the cast-iron shell is eleven times as thick as the wrought-iron shell. The sheet iron used in Winchester is no thicker than has been used in some other towns where pipe has rusted out badly. Iron 0.045 inch thick, if it happens to become exposed by the cracking of the cement, will soon rust through.

"A difficulty in the use of cemented sheet-iron pipe is the possibility of imperfect work. One square inch of poor cement covering per 100 feet in length might spoil the usefulness of a whole line.

"Winchester has been, as a whole, much more fortunate in its experience with cement pipe than most towns. Several reasons for the superior endurance of our older mains are very likely the facts that they are under rather moderate pressure from a gravity supply without pulsations of pumping and not subject to the water rams of elevator service, locomotive-tank filling, or the like; and that they mostly lie in firm, well-drained earth. Moreover, it is but fair to suppose that the workmanship and application of the cement covering have been unusually faithful.

"Still we average more leaks per year in the cement mains of Winchester than are found in the cast-iron pipe of all Lowell and Nashua combined.

"The experience of the great majority of cities and towns is that cement-coated sheet-iron pipe becomes so frequently leaky after from fifteen to twenty-five years of use that it is then condemned, dug up, and replaced by cast iron.

"The life of cast-iron pipe properly coated with coal pitch varnish, and with any ordinary earth and water, may confidently be expected to be fifty years, or perhaps even one hundred years for 8-inch pipe or larger. Commonly after five to fifteen years,

tubercles of rust will begin to form, and may gradually cover much of the interior surface with a crust 0.50 or 0.75 inch thick, thereby obstructing the water-way and retarding the flow still more by the roughness. If a pipe of generous size be laid at first, no other particular harm comes from this rusting. There are miles of Cochituate mains in Boston now in active service after a use of nearly fifty years, and which were laid without tar-coating. Cast-iron underground rusts much less rapidly than wrought iron.

"Malden and Melrose have both found it expedient to increase the pressure above that given by gravity from Spot Pond, which is at an elevation about four feet higher than the high-water line of our North Reservoir, and to pump the general supply to a higher distributing reservoir. The tendency of public works is to higher pressure, and perhaps Winchester some day may want a higher regular working pressure. Or, should it be desired at some future day, when a larger high-service reservoir has been provided, to arrange a valve at the central fire station, town hall, or police station (as could be cheaply done), by which instantly, on alarm of fire, the high-service pressure could be turned on the entire town, thus giving about eighty pounds per square inch fire pressure at all hydrants except those on the hill, or substantially the same as the common working pressure of a steam fire-engine, then this cast-iron pipe 'Class B,' which we have adopted for extensions of the past year will be, so far as it extends, perfectly adapted to such use.

"Charlestown was originally piped with cement-coated sheet iron. After fifteen to twenty years the leaks became so numerous that the whole was torn out and replaced by cast iron.

"Fitchburg has for several years past been tearing out each year its cemented sheet iron laid twenty-two years ago and replacing it by cast iron. It has now torn up about 20 miles, and has only 2 miles left.

"Worcester originally had 62 miles of cement-covered sheet-iron pipe, but found as it became old that it cost a great deal for repairing leaks and for damage by washouts. It has already dug up and replaced 53 miles of it with cast iron, and expects to tear out and replace all there is now remaining during the coming year.

"Manchester, N. H., put down many miles of the sheet-iron pipe at the original construction of its works twenty-two years ago, but has abandoned its use and lays only cast iron; and during the year past dug out nearly two miles of its 4-inch, 6-inch, and 8-inch, replacing the same with cast iron.

"The fire which nearly wiped out the business center of Spencer, Mass., two year ago, gained its destructive headway by reason of the water being shut off for a few hours to repair a rust crack in a cemented main.

"In Rome, N. Y., about a year and a half ago, the bursting of a

cement pipe main during a fire led to a property loss of upward of two hundred thousand dollars.

" In Somerville, Mass., the experience with the cement pipe for street mains was wholly unsatisfactory after the pipes became old, and the sudden development of a cold water geyser in the public street has, on one occasion at least, involved the city in a heavy claim for damages. At Lynn one similar burst of a cement pipe main is stated to have cost the city about ten thousand dollars for the broken windows and the general deluge, and they long since abandoned laying more.

" Coming nearer home and to water from the Middlesex Fells region, the same as our own:

" In Malden, the many breaks in the cement pipe were a serious obstacle to increasing the pressure on the pipes from the new distributing reservoir. The laying of cement pipe has been abandoned, and much of that originally laid has been dug up and replaced by cast iron.

" In Melrose they still lay some cement pipe, mostly in districts where pressure is low, but are laying cast iron for the important lines, and a member of their water board says they will probably soon lay cast iron exclusively.

" Medford abandoned cement pipe several years ago, and lays cast iron now exclusively. Medford had about ninety breaks on cement mains in 1893, and keeps a man at the shop day and night ready for repairs with a horse harnessed with a ' fire department quick-hitch ' for the cement pipe repair wagon. During the past year they tore up and relaid with cast iron about seven miles of cement pipe, but a part of this was done to obtained increased size in mains.

" Many additional examples could be quoted to show that Winchester in changing from cemented sheet iron to cast iron is very near to the conservative end of a very long procession.

"*Fourth.* Cement pipe even when filled with water is often struck by lightning and thereby ruined. Last year in our neighboring town of Arlington, a long piece of cement pipe was shattered from this cause and replaced by cast iron. Woburn has had similar disasters from cement-lined pipe struck by lightning. Lynn has suffered repeatedly from this cause, and Fitchburg has had similar experiences, and many other towns have had like accidents, sometimes $\frac{1}{3}$ mile of pipe being instantly ruined. In Winchester, in 1880, about 400 feet of the 6-inch high-service main was ruined from this cause and replaced.

" On the whole, Winchester has simply had unusually good luck in this matter of lightning damage.

"*Fifth.* Cast-iron pipe can safely be laid or repaired or cut into in freezing weather. Cemented pipe is endangered by frost spoil-

ing the set of the mortar exposed thereto, and, therefore, cannot safely be laid so early in spring or so late in the fall as cast iron.

"*Sixth.* Cast-iron pipe runs less risk of suffering from the accident of a careless workman. Each 12-foot piece having been tested under heavy hydraulic pressure at the factory, the joints are almost the only parts where leaks can occur from careless treatment, as by not filling or driving the lead joint properly. In a cement pipe, every square inch of surface is susceptible to injury from careless covering or lining, or from a lump of poor mortar. In soft ground, or ground disturbed by sewer work, cemented pipe will not resist straining so well as cast iron.

"*Seventh.* Cement-lined pipe has one great advantage over cast iron, namely, tubercles do not form on its interior surface. This remains clean and smooth and free from obstruction to the flow, even after twenty years of service.

"With cast iron, even though tar-coated, oxide of iron does commonly collect, the rate depending upon the quality of the water and the excellence of the tar-coating. Ultimately, perhaps in twenty-five to fifty years, this coating of hydrated oxide of iron may almost completely cover the interior surface; but even then with a 6-inch pipe there will probably be a 4-inch hole remaining open. Moreover, there is a device already in use in several cities having very old cast-iron pipe laid before the days of tar-coating, by which the tubercles can be scraped out of a pipe without taking it up. This device consists of a scraper actuated by the water pressure."

Early in the present year, 1908, to bring down to date the opinions formed in the various towns referred to in the above citations, the writer sent one of his assistants to interview the superintendents of water works in a number of our New England cities using pipe of this character, and to look up such references on the subject as he might be able to find. The result of these inquiries, together with some material collected in Lynn by Mr. E. V. French,* kindly placed at the disposal of the writer, and some inquiries and observations of the writer, are shown in the following memoranda:

ATTLEBORO, MASS. (Information from Mr. Geo. H. Snell, superintendent.)

In 1905 Attleboro had a population of 12 702. The works were constructed in 1873, cement-lined pipe being used for the mains. The further use of this pipe was stopped in 1880, and the

* Vice-President of the Arkwright Insurance Company, and a member of this Association.

work of replacing it with cast-iron was commenced in 1898. At the present time there is no cement-lined pipe in use. In 1880, 16 miles of the cement-lined pipe had been laid. The superintendent states that the use of this pipe was stopped because of the trouble in making connections and the liability of breaks at these points. When the system was first in use it was customary, in case of fire, to shut off all but the affected district, this being done because of fear of breaks due to the increased pressure from the pumps, the normal pressure of 65 pounds being raised to about 100 during fires. No figures are obtainable regarding the cost of repairs of this old pipe, as it was done by plumbers under contract. It is said that the number of breaks was large, the cost of repairs, involving the substitution of a piece of cast-iron pipe, running as high as $15 for an ordinary break.

The superintendent remembers trouble from lightning previous to 1881, when about seventy-five feet of main pipe was destroyed. The town is not provided with a system of sewerage, so that there has been no serious trouble from digging up of the streets.

Beverly, Mass. (Information taken from the published reports of the Water Board.)

In 1905 Beverly had a population of 15 223. The works were originally installed in 1869, water being obtained from Salem. In 1885 the works were enlarged, an independent supply was obtained at an increased pressure of about ten pounds. The effect of this pressure on the pipe is very noticeable, the average number of breaks from 1879 to 1886 being 63 per year. In 1887 the number of breaks was 249. The use of cement-lined pipe was practically abandoned in 1894, and in 1897 and following years the annual reports have clauses recommending the replacement of the cement-lined pipe with cast-iron on account of the poor condition of the old pipe.

Effect of Lightning. On August 10, 1878, 357 feet of 4-inch pipe was destroyed. On October 1, 1883, 600 feet of 4-inch pipe was destroyed. On July 23, 1888, one stroke of lightning caused three breaks. On June 17, 1892, one stroke caused several breaks and required replacement of 108 feet of pipe. In 1901, 2 000 feet were badly shaken by lightning and had to be replaced.

The size of pipe varies from 4 inches to 18 inches in diameter. Average pressure, 72 pounds. Average age of pipe, thirty-four years.

Following is a table of statistics relating to the leaks and cost of repairs:

Year.	No. of Leaks.	Miles of Cement-Lined Pipe.	Miles of Cast-Iron Pipe.	Total Cost of Repairs.	Cost of Repairs per Mile Cement Lined Pipe.
1888...........	206	49.0	1.1	......	.....
1889...........	103	....	...	......	.....
1890...........	121	50.0	1.4	......	.....
1891...........	194	50.3	2.4	$1 658.	$33.10
1892...........	271	49.5	3.9	2 179.	44.00
1893...........	149	49.5	4.9	1 507.	30.50
1894...........	148	49.6	5.3	1 522.	30.70
1895...........	146	48.2	7.2	1 577.	32.80
1896...........	...	...	...	......	.....
1897...........	74	47.3	9.5	2 875.	60.80
1898...........	152	46.0	19.7	6 250.	134.50
1899...........	160	46.0	11.3	2 193.	47.75*
1900...........	98	45.7	12.1	1 358.	29.80
1901...........	198	44.0	13.8	2 882.	65.50
1902...........	118	42.5	15.4	1 597.	37.60
1903...........	149	41.8	16.4	......	.....
1904...........	177	38.4	20.7	2 264.	49.00
1905...........	99	34.7	27.6	1 731.	50.00
1906...........	107	32.4	30.7	1 890.	58.40
		Average,		$2 249.	$50.45

Brockton and Whitman, Mass. (Information from superintendent of water works Horace Kingman, and city engineers Charles R. Felton, of Brockton, and Julius C. Gilbert, of Whitman.)

In 1905 Brockton had a population of 47 494, and Whitman of 6 521.

The only use of cement-lined pipe in Brockton is for a main connecting a reservoir with the city. This main consists of 20-inch and 24-inch pipe, and is about 15 000 feet long; half of it is through a country district, and the remainder through one of the streets on the outskirts of the city. This latter part of the main has numerous connections. The pipe was laid in 1880 and was made by dipping the wrought-iron shell in hot asphaltum and afterwards rolled in sand and cement before putting on the final coating. The main is under a varying pressure, which averages about 50 pounds.

* Figures previous to this date in some cases contain items other than those relating to repairs of leaks.

The superintendent states that no trouble whatever has been experienced with this pipe during the twenty-eight years of its existence.

In the town of Whitman there are about 12 miles of cement-lined pipe, and 12 miles of cast-iron. The works were installed in 1882–3, at which time cement-lined pipe was used for the mains. For all extensions since that time cast iron has been used. The superintendent states that the particular reason for using cast-iron pipe was that they had no appliances for making the cement-lined, and cast-iron pipe lends itself more readily to laying and to making connections. He says that practically no trouble has been experienced with the old cement-lined pipe, which has now been in use twenty-six years. The average pressure on the main is 65 pounds. The town is without a sewerage system and so there has been in the past very little digging up of the streets.

Concord, Mass. Population, 1905, 5 241.

The original works, consisting of a 10-inch supply main leading from Sandy Pond in the town of Lincoln to the town of Concord, and distribution pipe system from 3 inches to 8 inches in diameter, were built of wrought-iron cement-lined pipe in the year 1874. The pipe was of the socket type, known as the Knight-Bailey patent, but sleeves were also used outside of the socket joints in wet places and on curves. Branches were of cast iron. The wrought iron used in the shell was of the following gages:

Diameter, Inches.	Birmingham Gage.	Thickness, Inches.
3	23	0.025
4	22	0.028
6	20	0.035
8	19	0.042
10	17	0.058

The pipe was lined with 1 : 1 Rosendale cement mortar, and covered with a 1 : 2 mixture of the same. In wet trench the covering mortar was mixed in the proportion of 1 of cement to 1 of sand, or even richer. The joints were made with pure cement. The factor of safety upon the pipe system as a whole was supposed to be approximately 5, based upon an average head of 100 feet, or 43 pounds pressure per square inch, and a maximum head of 110 feet. The pipe was laid under contract by Ferris & Halliday, and

the contract cost thereof, as taken from the notes of the engineer for the town, Mr. William Wheeler, member of this Association, was as follows:

10-inch,	13 004.5	feet at	$1.57 =	$20 450.
8 ,,	996.5	,, ,,	1.22 =	1 215.
6 ,,	6 090	,, ,,	1.02 =	6 210.
4 ,,	10 375	,, ,,	0.76 =	7 890.
3 ,,	281	,, ,,	0.69 =	194.
Total,	30 747	feet,		$35 959.*

Mr. Wheeler estimated the cost of substituting cast-iron pipe for wrought-iron cement-lined pipe in this work at $41 100, cast-iron pipe being quoted in the year 1874 at $45 per ton, and having been quoted in the previous year at $65 per ton. The probable saving effected by the use of wrought-iron cement-lined pipe instead of cast-iron pipe at that time (1874) amounted, therefore, to a sum of $5 141, and it is interesting to note that subsequent developments have certainly justified the engineer's decision at that time on the score of economy to make use of wrought-iron cement-lined pipe in preference to cast iron for the following reasons:

The accumulation upon the saving of $5 141 compounded semi-annually at 6 per cent. (the rate of interest carried by notes or bonds issued by the town to cover the loan made for the water works) amounts to a present sum of approximately $19 500, and if we add to this amount 45 per cent. of $41 100 (the estimated cost of the cast-iron pipe system) to cover depreciation, based upon an annual allowance of ½ per cent. compounded annually at a rate of 5 per cent., and amounting approximately to $18 500, we have a total sum of approximately $38 400, which would more than cover the reproduction cost to date of a new cast-iron pipe line of even greater strength than that of the old wrought-iron cement-lined pipe. Had the price of cast-iron pipe been $25 per ton, the average ruling present-day price of cast-iron pipe, instead of $45 per ton, as it was at that time, the conditions would not have appeared so favorable.

It is worthy of note that the wrought-iron cement-lined pipe is still in use and that a high-service fire protection system is now being installed which will increase the pressure upon the greater

* Excluding 306 feet of 12-inch conduit in Sandy Pond.

CONCORD WATER WORKS.

Year.	Miles of Pipe, End of Year. Wrought Iron and Cement.	Cast Iron and Unlined Wrought Iron.	Total.	No. of Leaks on Cement-Lined Pipe.**	Cost of Repairs on C. L. Pipe.	No. of Leaks per Mile of C. L. Pipe.	Cost of Repairs per Mile of C. L. Pipe.
1874	5.58	0.63*	6.51	....	....§	....	....
1875	6.91	1.03*	7.94	....	....§	....	....
1876	6.91	1.03*	7.94	....	....§	....	....
1877	8.43	1.10*	9.53	....	....§	....	....
1878	9.79	0.60*	10.39	....	$18.25§	....	$1.86
1879	9.90	0.77*	10.67	....	51.05§	....	5.16
1880	9.90	0.99*	10.89	....	76.65	....	7.75
1881	9.90	0.99*	10.89	....	102.25	....	10.33
1882	9.90	1.13*	11.03	....	22.80	....	2.30
1883	16.65	1.15*	17.80	....	33.96	....	2.04
1884	19.71	0.97*	20.68	....	29.88	....	1.52
1885	19.71	1.10*	20.81	....	145.57	....	....
1886	19.71	1.11*	20.82	....	121.36†	....	....
1887	19.71	1.27	21.98	....	225.03†	....	....
1888	20.96	1.49	22.47	....	....	....	....
1889	20.96	2.42	23.38	....	No leaks	....	....
1890	20.96	2.59	23.55	....	No leaks	....	....
1891	20.96	3.14	24.10	....	....‡	....	....
1892	20.96	3.41	24.37	....	....‡	....	....
1893	20.96	3.52	24.48	....	....‡	....	....
1894	20.98	4.40	25.38	....	....‡	....	....
1895	20.98	5.36	26.34	....	....‡	....	....
1896	20.98	5.77	26.75	....	....‡	....	....
1897	20.98	6.12	27.10	....	....‡	....	....
1898	20.88	6.80	27.68	....	....‡	....	....
1899	20.88	7.03	27.91	....	....‡	....	....
1900	20.66	7.62	28.28	18	....‡	0.87	....
1901	20.65	8.58	29.23	19	....‡	0.87	....
1902	20.65	8.73	29.38	13	....‡	0.63	....
1903	20.62	10.96	31.58	14	....‡	0.68	....
1904	20.62	11.43	32.05	18	....‡	0.87	....
1905	....	....	....	20	....	....	....
1906	20.40	12.19	32.59	17	....‡	0.83	....
1907	20.35	12.40	32.75	10	....‡	0.49	....

* Mostly 1-inch to 2-inch tarred and enameled wrought-iron pipe. The first cast-iron mains were laid in 1880.

** No record from 1874 to 1899 inclusive.

† Includes renewals of services in 1887; whole amount devoted to this purpose.

‡ Data for this period cannot be separated from other items.

§ Repairs made by contractor.

part of these mains from 43 pounds per square inch to approximately 100 pounds. Undoubtedly some replacement of pipe will be required, but time alone can develop the extent of the replacement which will be necessary.

The laying of wrought-iron cement-lined pipe in Concord was abandoned in the year 1888.

Up to the present time repairs upon wrought-iron cement-lined pipe have not been excessive in cost, but they may prove so hereafter under the greater pressure.

The record of leaks and cost of repairs upon the cement-lined pipe has, unfortunately, not been kept separate in bygone years from that upon cast-iron pipe, or, indeed, from repairs upon other parts of the water-works plant. Such information as the writer has been able to gather, with the assistance of the present superintendent, Mr. Leonard C. Robinson, is contained in the tabulation on page 20.

Concord, N. H. (Information from Superintendent Percy R. Sanders.)

In 1900 Concord had a population of 19 632; a system of water works was installed in 1872, cement-lined main pipe being used. In 1883 a main from the source of supply to the city was laid, and in 1887 an extension to the village of Penacook was made. This completed the use of cement-lined pipe, all extensions since having been made with cast iron.

In 1898 the work of replacing the pipe laid in 1872 was commenced and is still in progress, as there remain about 14 miles of the 28 miles in existence in 1887. The pipe laid in 1883 and 1887 is still in use and, according to the superintendent, is in excellent condition, very little money having been expended upon it in repairs. The old pipe is being taken out because of the number of breaks caused by rust. There has been some trouble from lightning, in one case 388 feet of pipe being destroyed by this cause. The pressure on the pipe varies from 45 to 75 pounds, and some of the pipe is between the pumps and the reservoir. The sizes of pipe vary from 4 inches to 20 inches in diameter. Leaks have been recorded as follows:

Year.	Cost of Repairs.	No. Miles Cement-Lined Pipe.*	Cost of Repairs per Mile.
1900	$660.	29	$22.70
1901	485.	27	18.00
1902	432.	25	17.20
1903	309.	23	13.40
1904	496.	21	23.60
1905	237.	20	11.80
1906	260.	18	14.40

DANVERS, MASS. (Letter from Superintendent Henry Newhall.)

DANVERS, MASS., August 24, 1908.

MR. L. METCALF:

Dear Sir, — It seems impossible that your letter was dated July 21 and is unanswered. Besides my regular work, I have had 14 000 feet of 18-inch, 8 000 feet of 12-inch, and 7 000 feet of 6- and 4-inch *cast iron* to attend to, and to-day is the first day we have not worked. I hardly see how I could write anything for your meeting; my experience on cement-lined pipe has been largely in repairing an old pipe that was mostly *sand.* Mr. Blackmer has had experience in making and laying with both kinds, although the ancient kind was under low pressure. I will send you a pamphlet report of our committee. We lost the vote and so had to use cast iron. My opinion in brief *in re* cement-lined pipe is, that the Phipps double pipe is the best water pipe ever used, provided it can be made to use lead joints. We have used the 4-inch in a small degree, which worked satisfactorily, but when it came to finding out if an 18-inch could be made without the casting costing too much, and if it would stand the heavy calking necessary when empty, we were unable to do so. My experience has been unfavorable to cement joints made by regular water-works employees; in fact, in those made by men that called themselves experts, we have had *trouble* the *first year.* This seems to be the experience of a lot of water works men to whom I wrote. We wound them and in a few years they rot off. I now put on a split sleeve on all but the 4-inch, i. e., on the 8-inch and 12-inch, as the cheapest way to mend. You will see by the report I mail that we have only a little over a mile of the modern cement-lined pipe; most of the rest was laid or made thirty odd years ago. Our main is 12-inch, 3 miles long under 75 average pressure. We have had but one burst for ten years, but any quantity of joints leak. That is not so bad for a pipe where one-half sand was allowed in lining

* Includes the Penacook extension of about 4 miles, and a low service main of about 2 miles, which have as yet caused no trouble.

and a "cement mortar" for outside. The smaller sizes do not make so good a showing; from the appearance of the lining, I am inclined to think that a great deal of the trouble was due to imperfect mixing by hand; while some you can crumble in your hand perhaps a few inches away it is as hard as a rock. I didn't mean to write you but a few lines, but I am very much interested in cement-lined pipe, although I see no prospect in using it at present. If you think I could give you any information in the form of answering questions, I should be only too happy to do so. I do not belong to the Association as unfortunately I am too deaf to hear the proceedings.

Yours truly,

(Signed) HENRY NEWHALL.

Under date of May 22, 1907, a committee appointed by the town of Danvers to "look into the advisability of establishing a plant for the town to manufacture cement pipe to be used by the water department," presented an interesting report in which it discussed the relative cost of wrought-iron cement-lined and cast-iron pipe and concluded after careful consideration that it was "advisable to establish a plant for the town to manufacture cement pipe to be used by the water department."

Without in any way wishing to criticise the action of the committee, particularly as the local situation has not been examined by him, the writer desires to call attention to the fact that the committee based its findings upon cast-iron pipe at $30 per ton, and used in its computations a weight of cast-iron pipe which would give a strength far in excess of that of the wrought-iron cement-lined pipe with which comparison was being made. Inasmuch as, in the judgment of the writer, to make the computations strictly comparable, a considerably lower price for cast iron should have been used, since the ruling price of cast-iron pipe during the last twenty-five years has been approximately $25 per ton, as will appear from later discussion of this subject in this paper, and as a much lighter cast-iron pipe would have given equal strength and reliability with the wrought-iron cement-lined pipe, and as no allowance was made for the fixed charges resulting from the construction of a plant for the manufacture of wrought-iron cement-lined pipe, the comparison submitted by the committee does not appear to the writer to be quite fair, — particularly when the

difficulty of securing uniformly good work and reliability of the cement-lined pipe in service, as compared with cast-iron pipe, is given due weight.

Gloucester, Mass. (Information from Herman W. Spooner, Engineer.)

The Gloucester Water Supply Company was granted charter in 1881, which was transferred to Mr. George H. Norman in 1884. The plant was put into operation in the fall of 1884. In the year 1895 the plant was taken by the city of Gloucester. At that time the entire pipe system, amounting to approximately 23.5 miles, was of wrought-iron cement-lined pipe. Since that time nothing but cast-iron pipe has been laid, and approximately 4½ miles of the wrought-iron cement-lined pipe has been replaced with cast-iron pipe. At the present time the system comprises approximately 64 miles of pipe, of which approximately 19 miles are wrought-iron cement-lined pipe.

The use of wrought-iron cement-lined pipe was given up on account of its unreliability and the excessive cost of repairs. The majority of leaks were caused by rupture at the joints, though some were due to careless work in neighboring excavations and a few probably to electrolytic action. Thus, in the year 1906, out of 44 leaks and breaks in the cement-lined pipe, 23 were leaks in service pipes, 3 leaks or breaks in the mains, the latter and the leaks in the service pipe being caused by electrolysis.

On several occasions the cement-lined pipe has been injured by lightning. Thus, on September 6, 1896, 17 leaks upon one street were caused by lightning during a severe shower. It was then found necessary to shut off nearly three quarters of a mile of pipe, as the leaks appeared at regular intervals throughout the entire line along Mount Pleasant Avenue from Highland to East Main streets. Other instances of from 3 to 7 leaks have been noticed since that time, though of considerably less serious nature.

Greensburg, Penn. The original water works of the Westmoreland Water Company supplying Greensburg and a chain of adjacent towns lying about thirty miles east of Pittsburg, were

built in the years 1888 and 1889, using cement-lined pipe. The amount and prices paid under contract for furnishing pipe, hauling, ditching and backfilling, making joints, etc., were as follows:

Diameter.	Length.	Cost per Foot.
16-inch	6 602 feet	$1.80 (very light)
14 "	49 675 "	1.85
12 "	34 863 "	1.53
10 "	22 438 "	1.17
8 "	16 490 "	0.92
6 "	20 386 "	0.66
4 "	14 358 "	0.51

Total, 164 812 feet = 31.21 miles

With regard to the pipe system, the manager and treasurer of the Westmoreland Water Company, Mr. Murray Forbes, says:

Data on Material in Pipe.

" All the above pipe was known as ' Phipps,' viz., an excellent grade of tough wrought iron lined and covered with an excellent quality of neat cement. On the outside a light wrought-iron jacket was placed for protection during transportation and handling.

General.

" The characteristic territory through which this piping was laid is hilly, with a maximum head of about 375 feet. At several points the line passed marshy ground. On beginning operations there was an excessive leakage, which was subsequently hunted up, very carefully repaired, and upon test the pipe was found tight.

" The leakage was confined to:

" 1. Joints on straight pipe.

" 2. Specials.

" 1. The defective joints were invariably in certain sections, generally in low, wet, or marshy ground. In these places almost every joint was defective and apparently due to:

" *A.* Careless and defective joint making.

" *B.* Joint cement having been wet.

" *C.* Boozing of the joint makers.

" 2. The ' Specials ' were poorly and inadequately made, and many burst and leaked more or less, and practically all had to be removed and replaced with cast iron.

Experience.

"After the defects were made good in a systematic and thorough manner, this pipe has been admirable, and we have had little or no trouble.

"As a distribution pipe, there are several objectionable points.

"1. The tapping must be done by a saddle, which runs the expense up, and while we have possibly 5 000 taps on this pipe and have had very little trouble, honest care must be used in making them or there would be.

"2. The pipe is easily punctured, and in our towns of to-day where sewers, gas pipes, and telephone conduits are continually being dug over and across this pipe, a pick will go clean through it.

"As a supply pipe, I don't believe it has a superior. We have had it in service nineteen and twenty years (at our Derry, Penn., system, twenty-one years) and it is as clean on the inside as it was the day it was laid."

In further comment upon his experience with this pipe line so far as leakage goes, Mr. Forbes writes:

"I took a great deal of pleasure and interest in reading over your paper on 'Wrought-Iron Cement-Lined Pipe,' and think it admirable, and I agree with your conclusions, viz.,

"Disadvantageous for distribution systems.

"Satisfactory for supply systems when carefully and honestly made and laid.

"From 1889 to 1907 inclusive, we have repaired 1 615 leaks on cement-lined pipe. This work can be divided into two classes:

"Leaks hunted for, due to bad workmanship in construction, from 1889 to 1894	1 506
"Leaks breaking out from 1894 to 1907	109

"To further subdivide this latter period:

"Leaks, 1894 to 1898	67.	Average per year	13.4
,, 1899 ,, 1907	42.	,, ,, ,,	4.7

"In other words, after the cement-lined mains were put in tight and serviceable condition, although about twelve years old (laid in 1888), they held pretty well. However, I am only giving you these figures as interesting, for if I can present a paper I'll use them, but if I find it will be impossible for me to be present, I'll turn them over to you.

"I notice one point in J. W. Ledoux's letter of July 22, viz.,

" 'The Westmoreland Water Company's system is one of the first built and one in which the pressures are much greater in places than the pipe should have been made to stand according to the standard of manufacture.'

" This may be, to some extent, true, but the point of greatest pressure on the Immel-Dry Ridge 14-inch line was laid in August, 1888, and put in service in December, 1888, and has been so ever since. We had a great many leaks in this place, but finally got it all fixed up about 1894, since which time we have had almost no trouble at all.

" To my mind, this Immel-Dry Ridge 14-inch line is holding splendidly. In 1907 we cut in a 14-inch by 4-inch tee in the district of heavy pressure referred to, and the pipe was in fine condition. It may be, that in the next ten years we'll have trouble.

" We have other points where the pressure is heavy, but the figures for the last nine years don't indicate trouble so far. Less than five leaks a year on about thirty-nine miles under heavy head, in places, is not conclusive."

Lee, Mass. (Information obtained by Mr. A. A. Fobes from Dr. F. K. Chaffee, superintendent.)

The works were built about 1883 and comprised from 8 to 10 miles of wrought-iron cement-lined pipe. Last year there were three leaks upon the pipe system, but the general average is approximately five or six leaks per year. The cost of making repairs is approximately $25 to $30 per leak. This is larger than it might be as they repair by inserting a piece of cast-iron pipe and using two cast-iron sleeves. They do this as none of the present management know how to make cement pipe. The chief cause of trouble has been the rusting of the steel.

Some trouble has been experienced from lightning. In 1892 lightning struck the pipe on the top of one hill and came out on the top of another, about two thousand feet away; the pipe between these two points seems to have been damaged, as several leaks occurred on that section, covering in all a period of twelve years.

The greatest pressure on the mains is approximately ninety pounds.

The system is in good shape and is considered a valuable asset, but all new pipe laid is cast iron, as no one in Lee knows how to lay the cement-lined pipe, and they have no machine for making it.

Lynn, Mass. (Information from Superintendent D. A. Sutherland to Mr. E. V. French.*)

Extract from letter of Mr. Sutherland to Mr. French, dated February 8, 1908.

" I enclose a table showing the amount of cement-lined pipe in the system in the years 1875 to 1908 and the number of breaks each year. We have also inquired of the foremen in regard to

Year.	Length of Cement-lined Pipe. Miles.	Feet.	Leaks.	No. of Failures per Mile per Year.
1875	46	3 063	130 (34 from frost)	2.82
1876	46	4 287	94 (1 burst caused by sewer)	2.04
1877	47	1 049	79	1.68
1878	49	1 503	79	1.61
1879	49	1 503	102	2.08
1880	52	1 433	121	2.13
1881	56	849	104 (on pipe of all sizes)	1.85
1882	60	809	119 " " " " "	1.98
1883	62	2 144	92	1.48
1884	63	2 140	84	1.33
1885	63	3 474	105	1.66
1886	63	3 609	107	1.69
1887	63	3 609	99	1.57
1888	63	3 609	79	1.25
1889	63	1 533	106	1.68
1890	61	3 504	136	2.22
1891	60	2 119	114	1.90
1892	59	3 007	132	2.23
1893	57	2 755	119	2.08
1894	56	2 983	99	1.76
1895	54	5 271	167	3.09
1896	53	4 714	147	2.77
1897	51	4 590	102	2.00
1898	50	4 523	115	2.30
1899	48	2 139	142	2.95
1900	46	5 072	...	?
1901	44	4 358	82	1.86
1902	42	879	82	1.95
1903	41	2 903	94	2.29
1904	37	2 903	96	2.59
1905	34	3 217	113	3.32
1906	32	253	91	2.84
1907	28	1 721	91	3.25
			Average,	2.07

* Published through the courtesy of Mr. French, member Lynn Water Board, Vice-President Arkwright, Mutual Fire Insurance Company, and member New England Water Works Association.

the cause of the breaks of the cement-lined pipe, and their replies as to the cause were the same as what we told you Saturday night.

"I am also enclosing a clipping from the 1885 report which may be of some interest to you in regard to the cause of the pipe giving out. We have had no trouble with the large main from the ponds to the pumping station except a few leaking joints on the 20-inch pipe from the pumping station to the reservoir; and one burst on the 22-inch pipe from Birch Pond to the pumping station. The latter was supposed to be caused by some repairs being made on one of the gates in the gatehouse at that time. Since that time we have had no further trouble from this pipe. I would seriously recommend relaying the 20-inch pipe from the pumping station to the reservoir as soon as possible, as any trouble on this main might cripple our water supply to the city."

The clipping states that a number of leaks were caused by pick holes made during excavation for sewers, but that the worst bursts have been where the pipe has been damaged in previous years by excavation and covered up without giving notice of injury. In other cases the fault is from carelessness in laying the pipe, either not using a sufficient quantity of cement in covering the pipe or injuring cement while green in backfilling trenches.

The inner layer of cement was usually about one-half inch thick; the outer layer varying from one-half inch to three-quarters inch except at the bottom, where a sort of base was made. The pipe was received with the inner coating in place, was laid in a bed of cement in the trench, and then the outer cement covering put on by hand with rubber gloves.

In some places the covering is a good deal thicker than in others. In all cases Rosendale cement was used.

The cause of bursts is some flaw in the cement coating which allows the iron to gradually rust. In some cases the break is a small roundish hole; in others, a longitudinal crack. Where cracks occur, they are almost always longitudinal and seldom transverse to the pipe.

The joints were made by butting two lengths of pipe together, wrapping with a sheet of rubber, and winding the rubber with rope; then the whole was smeared with the Rosendale cement and a sheet-metal sleeve pushed over the joint outside the rope, and finally the whole covered with cement. The joints seldom give trouble and seem to be stronger than the main pipe.

Service taps are made by removing a little cement and punching out a hole in the iron, then the connection is soldered, using a soldering iron. The hole is then finally sealed with cement. These taps do not give trouble and do not seem to at all weaken the pipe.

The pipe laid in later years, 1881 to 1883, was covered with a black asphalt paint, and this seemed to considerably retard rust and make the pipe more durable.

The experience at Lynn was that for the first fifteen to thirty years there was not much trouble from bursts, then the pipe began to go and sections would frequently burst at so many places within a few years that they had to be removed as promptly as possible. It is said that pipe was first laid by contract and was not as well done as that put in later by the city, and consequently gave more trouble.

There is a 16-inch pipe from the pumping station to the reservoir which it is thought has never burst, to the best of the recollection of Mr. Sutherland and his son. The 22-inch from Birch, and the 18-inch from Breed, which are under light pressure, have never burst.

When there was a good deal of the pipe in use, breaks frequently occurred during fires. They are not now so common as the cement-lined pipe has been removed largely from the business sections, where most of the serious fires occur.

In the city streets the digging for sewers and other purposes does not disturb the cement pipes and cause breaks. Wherever cement was put on in a thorough manner, it is found, on knocking it off, that the pipe underneath is bright, with a bluish tinge, seemingly in just as good condition as when it was put in.

Test of 16-inch and 4-inch Cement-Lined Pipe, from Lynn, Mass., Water Works.

Specimens of the plate and longitudinal joints were secured and tested in a Riehle machine at the Massachusetts Institute of Technology, through the kindness of Professor Miller, and with the assistance of C. W. Mowry. These samples were more or less pitted and weakened on the surface by rust caused by exposure to weather, with the outside coat of cement removed.

The 16-inch pipe was laid in 1870 and remained in service until last fall. The shell is said to be sheet iron. It is riveted longitudinally by a single riveted lap joint. Each length of pipe consisted of 3-foot sections riveted together by single riveted lap joints. The rivets were iron and were riveted cold. The joints between lengths were made as described above.

The 4-inch pipe was probably laid about 1881–1883. The shell is said to be sheet iron. It is riveted longitudinally by a single riveted lap joint. The rivets were iron and were riveted cold. The joints between lengths were made in the same manner as in the case of the 16-inch pipe.

	16-Inch.	4-Inch.
Diameter of shell	$17\frac{1}{2}$ inches	$4\frac{3}{4}$ inches
Thickness of plate	$\frac{5}{64}$,,	$\frac{1}{32}$,,
Size of rivets	$\frac{1}{4}$,, (diam.)	$\frac{1}{4}$,, (diam.)
Pitch of rivets in longitudinal joint,	1 ,,	1 ,,
Pitch of rivets in ring seam	$4\frac{1}{4}$,,	....
Lap	$1\frac{1}{8}$,,	$\frac{7}{8}$,,

Result of Test, 16-Inch Pipe.

Tensile Strength per Inch of Width of Plate.

First specimen	3 159 pounds
Second ,,	2 567 ,,
Third ,,	3 098 ,,
Average	2 941 ,,

Strength of Longitudinal Joint per Inch of Width of Plate.

First specimen	2 057 pounds
Second ,,	1 920 ,,
Third ,,	2 060 ,,
Average	2 012 ,,

Load on pipe per inch of length, assuming 50 pounds steady water pressure on the interior of the iron pipe. No allowance was made for any strength in the cement lining or coating.

$$\text{Load} = \text{Pressure} \times \text{radius of pipe.}$$
$$= 50 \times 8.75 = 437.5 \text{ pounds.}$$

Efficiency of Joint.

$$\text{Efficiency} = \frac{\text{Strength of joint}}{\text{Strength of plate}} = \frac{2\ 012}{2\ 941} = 0.68$$
$$= 68 \text{ per cent.}$$

Factor of Safety.

$$\text{Factor of safety} = \frac{\text{Strength of joint}}{\text{Load on pipe}} = \frac{2\,012}{437.5} = 4.6.$$

RESULT OF TEST, 4-INCH PIPE.

Tensile Strength per Inch of Width of Plate.

First specimen..................	781 pounds
Second ,, ...	888 ,,
Third ,, ...	863 ,,
Average......................	844 ,,

Strength of Longitudinal Joint per Inch of Width of Plate.

First specimen..................	833 pounds
Second ,, ...	830 ,,
Average......................	831 ,,

Load on pipe per inch of length, assuming 50 pounds steady water pressure on the interior of the iron pipe. No allowance was made for any strength in the cement lining or coating.

$$\begin{aligned}\text{Load} &= \text{Pressure} \times \text{radius of pipe.}\\ &= 50 \times 2.375 = 119 \text{ pounds.}\end{aligned}$$

Efficiency of Joint.

$$\begin{aligned}\text{Efficiency} &= \frac{\text{Strength of plate}}{\text{Strength of joint}} = \frac{831}{844} = .98.\\ &= 98 \text{ per cent.}\end{aligned}$$

Factor of Safety.

$$\text{Factor of safety} = \frac{\text{Strength of joint}}{\text{Load on pipe}} = \frac{831}{119} = 7.$$

The failure of the plate in every instance was indicated by a sudden halt or drop in the scale beam showing practically no elasticity in the plate. In every fracture the lamina could be plainly seen and presented an appearance very much like wrought iron or mild steel.

The riveted joints failed by a bending action, which threw an eccentric load on the rivets. One side of the rivet was thus in tension and some were pulled apart, while the heads of others were pulled through the plate.

The joints between the lengths were made in such a way that

they could transmit practically no tension, and, therefore, the stress in the ring seam would be insignificant and can be neglected.

Effect of Lightning on Cement-lined Pipes at Lynn, Mass.

The following information was obtained by interviews with the superintendent and employees of the Lynn Water Works. No case of damage to cast-iron pipe caused by lightning could be recalled by them.

Chatham Street. (About 1896.) The 6-inch pipe in Chatham Street near Oakwood was struck by lightning. This caused a break necessitating the replacing of an 8-foot length of 6-inch cement-lined pipe. It was relaid cast iron.

Essex Street and Vicinity. (About 1898.) About ten years ago lightning struck in several places in the vicinity of Essex Street. The following is a list of the locations of the breaks, and damage done.

Street.	Size.	Repairs.
Liberty	8 inches	One 8-foot length replaced by cast iron.
Highland Square	8 ,,	One 8-foot length replaced by cast iron.
Essex (near Highland Avenue)	8 ,,	One 8-foot length replaced by cast iron.
Highland Avenue (near Essex)	4 ,,	One 7-foot length replaced by cast iron.
Highland Avenue (near Adams)	4 ,,	Four or five 7-foot lengths replaced by cast iron.
Adams from Highland Avenue to Rockaway Street	6 ,,	About fifteen breaks were either repaired or the pipe replaced, but finally it was necessary to relay all of the cement pipe.
Rockaway, between Adams and High Rock	8 ,,	Six or seven 8-foot lengths replaced by cast iron.
High Rock, Rockaway to Acorn,	6 ,,	All replaced by cast iron.
Adams, corner Rockaway	......	Gate broken.

Storm of June 7, 1904. In 1904 lightning caused breaks in Chatham, Ingalls, Ocean, and Acorn streets. The following list was obtained from expense slips of the department. This list shows the extent that cement-lined pipe is damaged upon being struck by lightning. One break will be repaired, the water turned on, and then the pipe will give way in some other place.

Chatham Street near Massachusetts Avenue, 6-inch pipe.

		Cost.	
June 7	Replaced one 8-foot length,	$23.18	
June 9 and 10	,, ,, ,, ,,	17.16	
June 12	Repaired break,	10.49	
June 11 and 12	,, ,,	11.53	
			$62.36

Ingalls Street, 6-inch pipe.

June 7	Replaced four 8-foot lengths,	$33.54	
,, 8	,, one ,, length,	14.74	
,, 9	Repaired split pipe,	13.87	
,, 10	Repaired break	3.12	
,, 11	,, ,,	7.00	
,, 11	,, ,,	4.29	
,, 12	,, ,,	2.34	
			78.90

Ocean Street, 6-inch pipe.

June 7	Replaced one 8-foot length,		15.41
	Total cost		$156.67

Acorn Street. There were fourteen or fifteen breaks in the 4-inch pipe. These were repaired or replaced by cast iron. The pipe was finally replaced from High Rock Street to Hollingsworth Street before it could be placed in service for any length of time. No record of these repairs could be found.

Laconia Court. (September 4, 1907.)

The damage here necessitated relaying three 7-foot lengths of 4-inch pipe.

Manchester, N. H. (Information from Supt. Charles K. Walker.)

In 1900 Manchester had a population of 56 987. Water was introduced in 1872, cement-lined main pipe being used. In 1877 the further use of this pipe was abandoned and the work of replacement begun. Trouble in making repairs is given as the reason for replacing with cast iron. The last of the old pipe, with the exception of 4 miles, was removed about ten years ago. The remaining 4 miles is still in use; part of the old pipe is used as a force main and part as a main from reservoir to city. The old force main was provided with cast-iron bells and lead joints. It is under a pressure of about sixty pounds. But one accident from lightning is recorded. At the time the work of replacement began there were

about twenty-six miles of main pipe in the city. No records are kept of the cost of making repairs.

MOORESTOWN, N. J. (Information received from Mr. S. K. Robbins, secretary and treasurer of the Moorestown Water Company.)

"We have used the cement pipe exclusively since the plant was first constructed in 1888, and found it very satisfactory. Pipes laid in 1888, which were disturbed and broken recently in laying a sewer, were found in excellent condition. Of late we have had trouble in making joints, and have been compelled to wrap all joints, an expensive method, which, added to the increased cost of pipe, makes the cost of putting it in so excessive that we are seriously thinking of abandoning it and laying iron pipe hereafter.

"Another objection is lack of confidence in the ability of this pipe and joints to withstand a pressure of 100 pounds. Our system has never been subjected to this without disastrous results to joints."

PITTSFIELD, MASS. (Information from Mr. A. A. Fobes, formerly city engineer.)

The works were built in 1855 of wrought-iron cement-lined pipe, which has been entirely replaced by cast-iron pipe.

The Water Commissioners stated under date of April 13, 1868, in their annual reports:

"But it is a fact which cannot be disguised that in this town they [cement-lined pipe] have failed; and the commissioners think in consequence of the following reasons:

"The mains were not laid deep enough.

"The sleeves connecting the joints were in a great many instances very carelessly put on.

"The sections of the mains were not always put evenly together.

"The water was let into the mains before the cement had thoroughly hardened. When the pipes were first filled, the water was let on with full force, without proper precaution, and the pipes were much injured."

The general causes leading to the reconstruction of the pipe of the system with cast-iron pipe appear to have been injury due to freezing on account of the shallow depth of the trench and poor workmanship.

Some of the reports also mention injury to the mains at different times by lightning.

The static pressure upon the system averages about sixty pounds, the maximum being approximately seventy-seven pounds.

Plymouth, Mass. The following information, kindly furnished the writer by the superintendent, Mr. Arthur E. Blackmer, speaks for itself. Clear, concise, and reliable, it is believed to be some of the most valuable data published thus far upon wrought-iron cement-lined pipe. Mr. Blackmer, and the previous superintendent, Mr. R. W. Bagnell, should receive full credit for it.

In substance it may be said of Plymouth's experience that they have a pipe which has given good satisfaction for many years under the conditions of their service; they are able to manufacture and lay it with some degree of economy; the maintenance of it is neither excessively expensive nor annoying; it furnishes them with clear, clean water; the friction loss in it does not appear to be excessive, and the original diameter of pipe remains substantially unchanged after years of service. Hence they naturally have no cause to regret the adoption of cement-lined pipe and have no hesitancy in continuing its use.

[copy.]

Plymouth Water Works.

Plymouth, Mass., February 4, 1908.

Mr. E. V. French, Boston, Mass.

Dear Sir,— Your letter of inquiry regarding cement-lined pipe at hand. I am pleased to answer your inquiries as far ar I am able. I can, perhaps, give you our experience with cement-lined pipe best by giving you a brief history of the Plymouth water works.

In 1855, when the town took over the water works from a private company, the first cement-lined pipe was laid, 10 inches in diameter, from Little South Pond (about 17 000 feet from the center of the town, and 105 feet above mean low water) to a distributing reservoir in the center of the town. The distributing pipes, of 4-inch and 6-inch sizes, laid at the same time, were also cement lined.

In 1885, the gravity supply through the above-mentioned 10-inch line proving insufficient, a pump was installed at Lout Pond, on the line of the 10-inch main, about half way between town and Little South Pond. A check valve was placed on the 10-inch line, and the pump took water from the 10-inch main above the check valve, and forced it to town below the check. During the time the pump was in operation the distributing reservoir was cut off.

A few years later a high-service reservoir, 165 feet above mean low water, was built near the pumping station, and at the same time a 16-inch cement-lined main was laid from Little South Pond to the station, and a 14-inch cement-lined main from the station to the distributing reservoir in town. At this time the town was divided into high- and low-service districts, the low-service being supplied through the 16-inch and 14-inch mains, and low-service reservoir near town; the high-service was supplied by pump, high-service reservoir, and 10-inch main; and these have been the conditions up to 1907.

The 16-inch and 14-inch mains above referred to, as far as I can ascertain, have never been repaired. The 10-inch main from high-service reservoir to town has given considerable trouble during the last five years, and we replaced it last year by a 16-inch main, of the Phipps patent, or double pipe, as it is sometimes called.

The 16-inch pipe we manufactured in our own workshop, and in the coming spring we are to manufacture some 18-inch, to lay from the pumping station to Little South Pond, replacing the 10-inch laid in 1855. We have about fifty miles of cement-lined mains now in use, some of the old style and some of the new.

Our chief, in fact our only, trouble with new style pipe thus far has been with cemented joints, and a leaky cement joint will make itself known at once.

On the new 16-inch main referred to, laid in 1907, 6 800 feet have been in use since December 15 and not a leak has thus far developed. I think you assigned the correct reason for a great deal of the trouble that has arisen through the use of the old style cement pipe, that is, defective workmanship, in both making and laying pipe, as we have found holes rusted through the iron shell, due to imperfect lining, or imperfect covering of the pipe in the trench. This refers of course to our old pipe.

With our present method of lining and covering the shell, we reduce these imperfections to a minimum, if, indeed, we do not entirely eliminate them. We of course have a great advantage over cast-iron pipe in point of cost, for the 16-inch we have just made and laid cost us $1.24 per foot to make, which I believe was a saving of about 50 per cent. over cast-iron pipe of same size last October.

There is another point which, it has always seemed to me, has not received sufficient attention in any discussion of the relative merits of cast-iron and cement-lined pipe, if I may take your time for a hypothetical discussion.

Assume a town of, say, 15 000, to have 50 miles of pipes, and assume again (which I am not ready to admit) that it is desirable to limit cement-lined pipe to 100 pounds pressure, and cast-iron to 150 pounds; would the fire protection of that town for a period

of, say, thirty years be any more efficient with its 50 pounds additional pressure on cast-iron mains and distributing pipes, more or less encrusted as they are bound to be during that period, than would the 100 pounds on the cement-lined system, which we are absolutely sure would retain its original size during the same period? * I am, of course, aware that the above question is not susceptible of exact analysis, but I believe it is a point that is frequently overlooked. With reference to further information on this subject would say that the American Pipe Manufacturing Company, of Philadelphia, own several systems in which they have cement-lined pipe, and Mr. E. H. Phipps, St. Paul Building, New York, may be able to inform you further.

Yours very truly,

A. E. Blackmer.

MANUFACTURE AND USE OF CEMENT-LINED PIPE AT PLYMOUTH, MASS.

Plymouth is a town of about eleven thousand inhabitants and has had a water supply since 1796. Until 1855 the water was supplied to the town by a private company and the pipes they used were wooden logs with holes bored in them. In 1855 the town purchased the plant from the Aqueduct Company, and the use of cement-lined pipe in Plymouth dates from that period.

At that time about sixteen thousand feet of 10-inch pipe was laid and several thousand feet of 8-inch, 6-inch, and 4-inch pipe were laid for the distribution system. Practically all of the pipe laid at that time is still in use.

The pipe as then manufactured consisted of a sheet-iron shell about 9 feet in length, lined on the inside with about one-half inch of cement mortar, composed of cement and sand in proportions of 1 to 1. The pipe was then laid in a bed of cement mortar in the trench, ends butted together, with a steel sleeve or collar at each joint. The top and sides of the pipe were then covered with two or more inches of cement mortar, all of the same proportions as used for the lining, and a cement-mortar joint was made at each joint of the pipe.

This pipe is still in use and withstands a varying pressure in different sections, from a few pounds to about fifty pounds.

* See also concluding discussion, bearing upon coefficient discharge at Plymouth, on page 63.

In 1900, somewhat over forty miles of pipe from 4 inches to 20 inches in diameter was in use. At this time a change in the method of making the pipe was introduced, and for the past seven years all extensions have been made with a pipe manufactured in the local water-works shop, which is furnished with mechanical devices and power machinery necessary for economical manufacture.

The following description, with the accompanying photographs of the pipe as at present made, will, it is hoped, make the present method of construction clear. The pipe consists of a shell, a jacket, male and female rings, and sleeves. The shells and jackets are of soft steel and are received at the shop in flat rectangular sheets of proper size and gage. The photographs show the construction of some 18-inch pipe made at the water-works shop. For the shells of this pipe about thirty tons of steel sheets of No. 13 gage were used, at a cost of about fifty dollars per ton for the sheets.

The gage of the sheets used for the shells of pipes of different sizes varies with the size of the pipe from No. 13 gage for 18- and 16-inch pipe to No. 20 for the smallest sizes down to 4-inch.

24-inch	12 gage
18 ,,	13 ,,
16 ,,	13 ,,
12 ,,	15 ,,
10 ,,	17 ,,
8 ,,	18 ,,
6 ,,	19 ,,
4 ,,	20 ,,

The jackets are all No. 26 gage iron. Plate I, Fig. 1, shows the sheets in the shop ready to be made up into pipe, and one shell going through the punching machine.

The operation of making the pipe is as follows:

The shells are punched in the punching machine shown in the illustration; the spacing of the rivet holes is $\frac{3}{4}$ inch from center to center, the edge of the rivet hole being $\frac{5}{8}$ inch from the edge of the sheet. The sheets are then put into the rolls and given a semicircular form, as two sheets are used for the manufacture of one shell for the 18-inch pipe. After being rolled, the shells are riveted by hand, using 816 rivets with a $3\frac{1}{2}$-pound hammer, on a stake, so-called, which is simply a bar of iron about ten feet long,

the upper surface of which is curved to approximately the same radius as the shell of the pipe which is to be riveted. The jackets are punched, rolled, and riveted in precisely the same manner as the shells and are $1\frac{1}{2}$ inches larger in diameter. (Plate II, Fig. 1, shows quite clearly the riveting process.)

The rings are of cast-iron, a male ring for one end of the shell and a female ring for the other, the female ring being concave and the male ring convex, thus enabling a very tight joint to be made when the pipes are fitted together in the trench. About thirty tons of these rings were used in the manufacture of 16- and 18-inch pipe during the past year and the cost of the rings was 4 cents per pound.

The next operation, after the shells are riveted, is the fitting in of the rings, and as they are made just for a driving fit into the shell they are driven in by use of the maul. After the rings are in place the shells for the 18-inch, 16-inch, and 14-inch pipes are lined by hand, and the smaller sizes of shell from 12-inch to 4-inch are lined by means of a revolving cone. Neat Rosendale cement is used in lining. About three thousand barrels of cement have been used during the past year in the manufacture of pipe, and the cost was $1.20 per barrel, delivered at our shop.

When the shells are ready to be lined by hand they are placed horizontally on two horses. A man stands at each end of the pipe with a long-handled pallet knife, so-called, to spread the cement smoothly in the pipe. This knife is simply a flat blade about one and one-half inches wide and four inches in length, with a handle about four feet long. The cement for lining is mixed by hand in mixing boxes, and there are two men to mix for the two men who line. As the pipe lies on the horses it is lined for its whole length and half way up each side. Then the cement is allowed to set, after which the pipe is rolled over and the remaining half lined. After the cement has been smoothly spread about one-half inch thick, on the inside of the pipe, any irregularities which appear are corrected by the use of the "nigger-head," which is a stiff brush on the end of a long handle. This brush in the hands of a skillful workman can bring the interior of the cement pipes to a very smooth surface.

At this point it may be well to describe the operation of lining the smaller sizes of pipe. The shells having been punched, rolled,

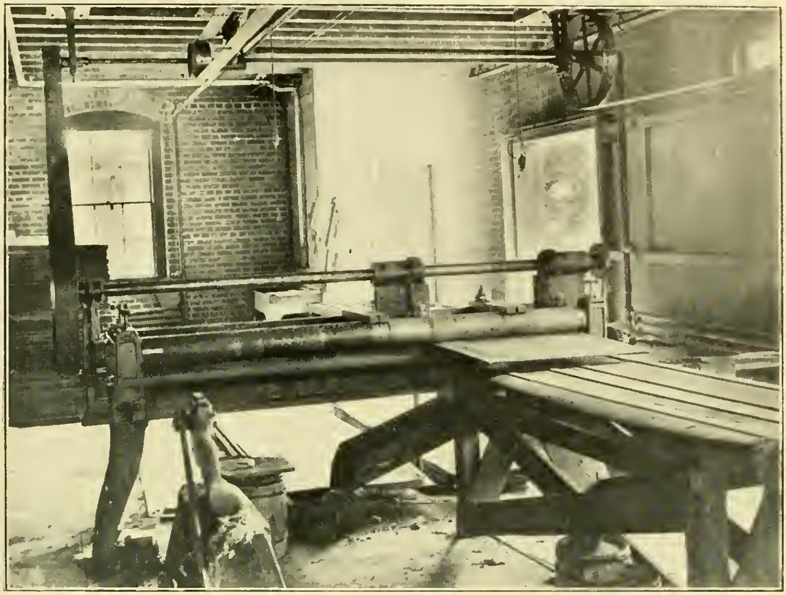

FIG. 1. PUNCHING THE SHEETS.

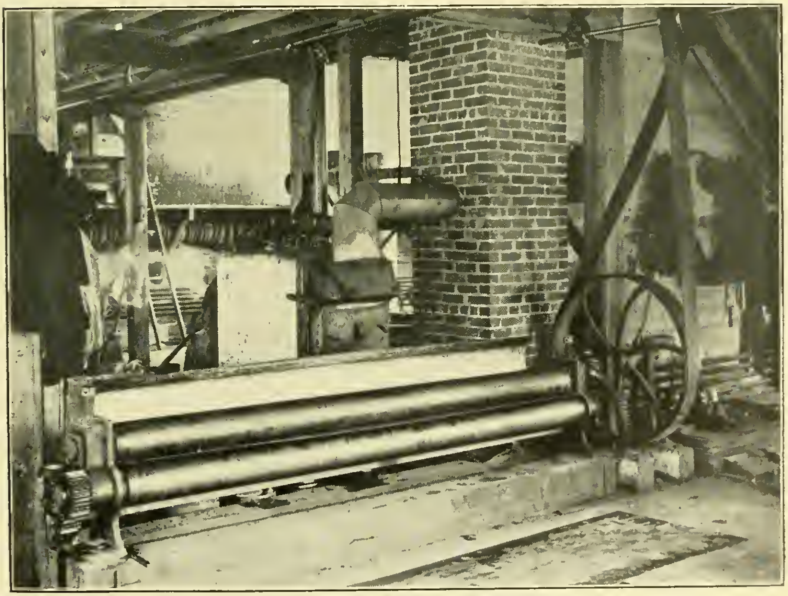

FIG. 2. ROLLS FOR SHAPING THE SHEETS.

FIG. 1. RIVETING THE PIPE.

FIG. 2. PUTTING IN CEMENT LINING.

FIG. 1. PUTTING OUTER SHELL ON PIPE; PREPARING FOR POURING GROUT.

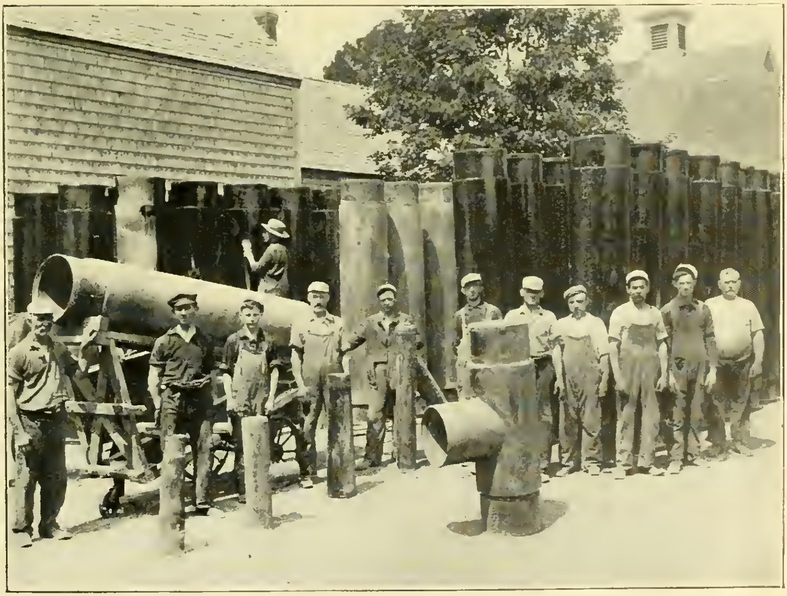

FIG. 2. STACKING AND PAINTING PIPE IN YARD.

and riveted, and rings put in in precisely the same manner as previously described, are stood upright on an elevator which descends into a pit. In this pit is the cone, so-called, which has an external diameter equal to the internal diameter of the shell when lined, — in other words, about an inch smaller in diameter than the shell — placed and held directly over it on the elevator. The cone revolves on a vertical axis and cement mixed by machinery is put in at the top of the shell as it stands on the elevator over the cone. The top of the cone, extending for a few inches into the bottom of the shell, holds the cement from falling through into the pit. The elevator holding the shell is then lowered and the cone revolving at the same time spreads the cement smoothly and uniformly on the inside of the shell.

The next operation is filling and grouting the pipe. The shells are stood on end around the edge of a platform which is about six feet above the floor. A clamp is placed around the bottom of the shell about eight inches from the lower end, and the jacket lowered from above fits into the clamp at the bottom. The jacket is kept symmetrical with the shell at the bottom by means of this clamp, and at the top by means of four wedges. The grout is merely a mixture of neat cement and water, mixed to such a consistency that it will pour readily, and is mixed by machinery in a cylindrical mixer which has four paddles. After being thoroughly mixed, the grout is poured into a metal bucket which is suspended by a chain with a wheel and is carried on a track around the platform. The grout is poured from the bucket between the shell and jacket of the pipe that has been stood around the edge of the platform. After the grout has been poured, the pipes are allowed to set twelve hours, when the cement is usually hard enough to permit of handling them. Plate III, Fig. 1, shows the method of placing the jackets and pouring the grout in the pipe. The pipes are then loaded upon a truck as shown in the photo, taken to the yard, cleaned, and painted with a coal-tar paint. After staying in the yard about two weeks they are sufficiently hard to permit of being loaded upon a wagon and carted to the trench.

Tables Nos. 1 and 2, which follow, show respectively the cost of making and laying the largest cement-lined pipes which have been made at Plymouth. Town labor, only, is used, and $2.00 is the

TABLE No. 1.

Cost of Making Cement-Lined Pipe at Plymouth, Mass.

Date.	Size Pipe, Inches.	Length Feet.	Shell.	Jacket.	Sleeve.	Rings.	Rivets.	Cement.	Paint.	Labor.	Total.	Cost per Foot.
1901	6	5 282	$650.94	$326.90	$42.25	$154.17	$25.98	$356.30	$7.14	$513.30	$2 076.98	$0.393
1901	4	2 461	186.20	104.74	12.37	43.89	12.29	162.15	1.50	281.25	804.39	0.326
1901	10	5 097	1 146.08	407.43	88.42	255.17	36.42	551.55	10.67	885.45	3 381.29	0.663
1901	6	2 007	221.34	100.71	14.02	58.18	10.03	135.41	2.66	177.09	719.44	0.358
1901	12	981	305.28	182.40	25.07	55.12	7.00	121.26	2.67	177.08	875.88	0.893
1907	16	8 109	3 722.80	852.72	337.50	1 363.35	61.90	1 728.00	15.00	1 954.42	10 035.69	1.24
1907	14	2 183	953.44	199.40	59.00	318.60	23.60	384.68	5.00	535.72	2 479.40	1.13
1907	18	7 680	3 751.60	896.40	298.80	1 460.80	119.00	1 826.00	18.00	2 457.60	10 828.20	1.41

TABLE No. 2.

Cost of Laying Cement-Lined Pipe at Plymouth, Mass

Date.	Size Inches.	Length Feet.	Labor.	Branches, Gate and Hydrant.	Pipe.	Cement.	Miscellaneous.	Total.	Cost per Foot.	Remarks.
1901	12	1 292	$861.90	$418.81	$1 128.62	$70.20	$55.00	$2 534.53	$1.96	Also 47 feet 6-inch pipe.
1901	10	5 430	2 478.28	1 292.21	3 583.47	205.40	173.48	7 732.84	1.43	105 ft. 6-inch, 77 feet 12-inch, 40 feet 8-inch
1901	12	1 292	458.40	108.72	1 153.76	52.00	54.22	1 827.10	1.41	
1904	8	3 007	1 035.66	275.67	1 503.50	91.20	72.99	2 979.02	0.99	
1904	6	2 543	1 134.97	412.33	933.28	61.88	37.55	2 584.01	1.02	
1905	6	4 550	1 854.23	491.38	1 966.16	96.00	385.82	4 793.59	1.05	Includes 4 hydrants and changing 25 services
1907	18	6 545	4 248.80	232.00	9 228.45	440.60	523.60	14 673.45	2.24	
1907	14	2 031	552.52	141.00	2 295.03	124.20	86.00	3 201.27	1.56	
1907	16	8 891	4 820.00	1 411.12	11 024.84	420.00	1 179.39	18 855.35	2.12	

RECORD OF LEAKS AT PLYMOUTH, MASS.

Year.	No. Miles Pipe.	No. Leaks.	No. Leaks per Mile.	Total Cost Leaks.	Cost per Mile.	Cost per Leak.
1874		9		$47.30		
1875		53		249.45		
1876		8		42.75		
1877		9		42.87		
1878		14		43.05		
1879		7		23.25		
1880	19.6	57	2.85	253.11	$12.90*	$4.44
1881	20.34	72	3.54	321.06	15.74	4.46
1882	20.54	33	1.6	159.22	7.75	4.83
1883	20.85	22	1.05	159.52	7.65	7.26
1884	21.52	46	2.13	263.46	12.24	5.73
1885	21.75	30	1.32	174.28	8.01	5.81
1886	23.6	38	1.61	231.91	9.82	6.10
1887	27.37	55	2.0	385.64	14.09†	7.02
1888	28.21	89	3.15	592.29	20.96	6.66
1889	28.7	31	1.08	261.90	9.13	8.45
1890	29.05	32	1.1	150.63	5.18	4.71
1891	29.23	35	1.18	201.79	6.90	5.77
1892	32.00	35	1.09	207.83	6.49	5.94
1893	33.09	39	1.11	204.74	6.19	5.24
1894	33.4	41	1.22	241.02	7.22	5.88
1895	34.32	34	.99	179.91	5.24	5.29
1896	34.45	46	1.34	310.13	9.00	6.74
1897	35.00	50	1.43	389.10	11.12	7.79
1898	35.17	42	1.2	232.84	6.62	5.54
1899	36.07	109	2.71	468.42	12.98‡	4.30
1900	37.33	58	1.55	402.35	10.78	6.94
1901	44.43	102	2.29	733.42	16.50§	7.19
1902	45.56	81	1.77	782.07	17.16	9.66
1903	45.8	54	1.20	496.81	10.90	9.20
1904	46.44	59	1.27	438.75	9.44‖	7.44
1905	46.88	41	.87	516.40	11.02‖	12.60
1906	47.33	25	.53	315.40	6.67	12.61
1907	49.43	26	.52	622.45	12.56**	23.92
Average, (1880-1907.)	33.12	49.36	1.49	$349.86	$10.56	$7.09

* 1880. Pump started April, 1880.

† 1887. High service put on December 20, 1887, causing many extra leaks in pipe thirty-four years old, never before exposed to high pressure.

‡ 1899. Lightning caused 30 or 40 leaks.

§ 1901. Twelve leaks occurred in old 2-inch galvanized iron. Since replaced.

‖ 1904 and 1905. Extremely cold; frost many places 5 feet deep; 360 feet pipe lowered.

** 1907. This year one leak was very expensive. Frost was 5 feet deep. Leak did not appear on surface for several days, causing a settling in sidewalk and street, which had to be replaced.

wage paid for a working day of eight hours, for each laborer. The foreman receives $3.00.

The pipe-making gang numbers about sixteen men, but only four are kept on the regular gang and the others are hired as they are needed.

Upon friction loss in their cement-lined pipe, Mr. Blackmer says, —

"I find in our records a report made to the Plymouth Water Commissioners by Mr. Clemens Herschel, dated September 1, 1875. In this report he states that he measured the discharge of our 10-inch main from Little South Pond to our distributing reservoir in town, a distance of about 16 000 feet under a six-foot head, and found it to be about 10 500 gallons per hour.

"If I have made no error in computation, this corresponds to a value of C = 93 in the Chezy formula. [This corresponds to C = 103, approximately, in the Hazen and Williams formula. L. M.]

"I have also a section of 10-inch main (now being replaced by 18-inch) from Little South Pond to our pumping station at Lout Pond, a distance of 7 500 feet. This main discharges freely into Lout Pond under a head of approximately 18 feet, but subject to some variation. Lout Pond is about fifteen acres in extent, with a very small watershed. For two years I have kept daily records of the height of this pond and put it on a sheet with our daily pumping record. From this sheet it is apparent that when our daily average pumping exceeds 750 000 gallons, Lout Pond falls, and when our pumping falls below 700 000 gallons, Lout Pond rises. I have assumed from this (but with what per cent. of error I do not know) that the capacity of this 10-inch main was between 700 000 gallons and 750 000 gallons in twenty-four hours. Assuming that 725 000 gallons is approximately correct, I obtain a value of C = 90 in Chezy formula. [This corresponds to C = 109, approximately, in the Hazen and Williams formula. L. M.]

"I am aware that these data may not be exact, but they are all that appear to be on record, and I hope may be of interest to you."

Portland, Me. (Information developed in the valuation proceedings in the suit of the Portland Water District *v.* Portland Water Company *et als.*, March, 1908.)

In the years 1868–9 the Portland Water Company laid a 20-inch wrought-iron cement-lined supply main, about 15.2 miles

long, from Sebago Lake to the city of Portland. Data as to the cost of this main are unfortunately lacking.

In the years 1875–9, however, a second wrought-iron cement-lined supply main was laid from the lake to the city. The upper portion of this, approximately 3½ miles in length, was 26 inches in diameter; the lower portion, approximately 11.4 miles in length, 24 inches in diameter. The actual cost of this compound main was fortunately developed from the books of the company and is given in substance below, as some of the unit costs to be derived therefrom are interesting and valuable.

(The original pipe distribution, comprising pipes from 4 to 16 inches in diameter, was also laid of wrought-iron cement-lined pipe, but substantially all of this was abandoned within a period of twenty years, and relaid with cast-iron pipe, and figures of its cost are not available.)

It should be stated that the static pressures upon this supply main are approximately as follows:

4	miles,	under	0– 40	pounds	pressure	per	square	inch.
2.7	„	„	40– 60	„	„	„	„	„
4.9	„	„	60– 80	„	„	„	„	„
2.3	„	„	80–100	„	„	„	„	„
0.9	„	„	100–120	„	„	„	„	„

The main is stated to have been built with a factor of safety of approximately 3, but the computation of the factor of safety under several assumed heads indicates that the actual factor of safety is probably not in excess of 1.5 at the points of maximum pressure, assuming always static pressures, and ignoring alike the decrease in pressure due to friction and the increase in pressure due to water hammer or other causes.

Strength of Riveting of Wrought-Iron Cement-Lined Pipe between Sebago Lake and Portland.

Wrought-iron plate, No. 12 and No. 14 gage; tensile strength	60 000* lbs. per sq. in.
Wrought-iron plate, No. 12 and No. 14 gage; bearing strength	60 000* „ „ „
Rivets of wrought iron; shearing strength	50 000 „ „ „
For field riveting, allow, shearing strength	40 000 „ „ „
Efficiency of best single riveted joint	55%
Efficiency of best double riveted joint	70%

* For $\frac{3}{16}$ inch and heavier plate, tensile strength = 50 000 lbs. per sq. in.

March 27, 1908, examined another section of 20-inch cement-lined pipe and found following measurement:

Internal diameter of wrought-iron cement-lined pipe......	$19\frac{3}{4}$ in. and $19\frac{3}{4}$ in.	24 in.	26 in.
External diameter of wrought-iron shell................	22 ,, ,, $21\frac{3}{4}$,,	26 ,,	28 ,,
Type of joint................	Slip	Sleeve	Sleeve
Gage of plate (Birmingham)..	14	12	12
Thickness of plate............	0.083 in.	0.109 in.	0.109 in.
Rivets, diameter..............	$\frac{1}{4}$,,	$\frac{3}{8}$,,	$\frac{3}{8}$,,
Rivets, pitch................	$1\frac{1}{4}$,,	1 ,,	1 ,,
Riveting....................	Single	Single	Single

Under Assumed Head of 250 Feet (= 108 Pounds per Square Inch) from Sebago Lake:

Tension on plate, pounds per square inch.........................	14 200	12 900 (Note A below)
Factor of safety (60 000).........	2.3	2.6
Shear upon rivets, pounds per square inch..................	29 900	12 700
Factor of safety (40 000)........	1.4	3.1
Bearing upon plate, pounds per square inch..................	70 700	34 400
Factor of safety, (60 000) (Based on 100 000 pounds = 1.4)	Failure	1.7

Under Assumed Head of 200 Feet (= 87 Pounds per Square Inch) from Full Standpipe.

Tension on plate..................	11 400	10 400 (Note A below)
Factor of safety................	2.8	3.2
Shear..........................	24 000	10 100
Factor of safety................	1.6	4.0
Bearing.........................	56 500	27 500
Factor of safety (Based on 100 000 pounds = 1.8)..............	Failure	2.2

Under Assumed Head of 150 Feet (= 65 Pounds per Square Inch) from Bramhall Reservoir.

Tension on plate..................	8 500	7 700 (Note A below)
Factor of safety................	3.9	4.3
Shear..........................	18 000	7 600
Factor of safety................	2.2	5.3
Bearing.........................	42 500	20 700
Factor of safety (Based on 100 000 pounds = 2.4)	1.4	1.5

NOTE: No allowance for water hammer. A factor of safety of 1.0 is equivalent to failure.

NOTE A. The 26-inch is under very small pressure.

In comparison with these factors of safety of $1\frac{1}{2}$ to 3 or more, it should be noted that modern steel pipes are usually built with a factor of safety of 5 (or at least 4) and cast-iron pipes with a factor of safety of 15 more or less.

COST OF BUILDING 24-INCH WROUGHT-IRON CEMENT-LINED SUPPLY PIPE FROM END OF 26-INCH PIPE ON WARD'S HILL TO THE CITY OF PORTLAND.

Length, 60 221 feet.

The work was substantially done in the year 1878–9.

ACTUAL COST. (1878–9.)

Rights of way, land damages, etc.		$1 579.14
Cast-iron pipe, specials, castings, valves, etc.		5 024.08
Wrought-iron sheets for pipe:		
441 502 pounds at 2.43 cents	$10 728.50	
1 449 562 ,, ,, 2.30 cents	33 339.92	
		44 068.42
Making pipes 9 feet long: 1 593 pieces at $2.15, and 5 073 ,, ,, 2.00		13 570.95
Making joint rings, inside rings, and special rings: 7 061 rings, weighing 646 310 pounds, at 1.95 cents, approximately, per pound		12 615.14
Total labor, 24 775 days at $1.28 approximate average; day labor being paid from $1.00 to $1.25; foremen, $3.50		31 807.11
Cement, 20 621 barrels Rosendale		20 180.50
Freight, cartage, etc.		4 148.91
Engineering, incidentals and miscellaneous expenses, amounting to 8.32 per cent. approximately		10 919.67
		$143 913.92
Deduct land damages		1 579.14
Net amount		$142 334.78
Cost per foot		$2.36
Equivalent cost per foot for year 1908 (estimated)		$3.02

COST OF BUILDING 26-INCH WROUGHT-IRON CEMENT-LINED PIPE FROM SEBAGO LAKE TO THE JUNCTION ON WARD'S HILL WITH 24-INCH PIPE LEADING TO THE CITY OF PORTLAND.

Length, 18 450 feet. Date of construction, 1875–6.

	Per Lb. Cents.	Actual Cost in 1875–6.	Equivalent Prices as of 1908.
Wrought iron sheets, No. 12 Birmingham gage, 635 679 pounds at	3.32	$21 230	$18 670
Trimming, rolling, riveting, and finishing 2 066 pipe 9 feet long at $2.50, equivalent to	0.78	5 020	4 430
Rings	0.90	5 590	4 920
Equiv. rate per lb., 1875–6	5.0		
,, ,, ,, ,, 1908	4.4		
Cement (Rosendale), 74 071 barrels at $1.36 and $1.53½ per bbl		10 170	7 500
Contract for laying		28 310	42 465
Valves		237	237
Specials		85	85
Lumber		608	1 074
Contract work		141	150
Total		$71 391	$79 531

Cost per foot (including 11.4 per cent. for engineering and contingencies)	$3.87	$4.31

The cost of this 26-inch pipe line was excessive, owing to deep cut work, a considerable amount of which was in quicksand.

Mr. Allen Hazen, member of this Association, who was one of the engineers retained by the Water District in the valuation of the Portland water works, made the following interesting analysis of these items of cost:

ESTIMATE OF COST OF REPRODUCING CEMENT–LINED PIPE AT PORTLAND.

	26-Inch.		24-Inch.		20-Inch.
	Actual Price and Quantity.	Estimates for Present Conditions.	Actual Price and Quantity.	Estimates for Present Conditions.	Estimates for Present Conditions.
Cost of sheets, per pound ...	$0.0342	$0.0275	$0.0233	$0.0275	$0.0275
Cost of cement, per barrel....	1.40	1.00	0.98	1.00	1.00
Cost of joint castings, pound,	0.0280	0.0275	0.0195	0.0275	0.0275
Cost of making pipe, per pound..................	0.00756	0.0125	0.00718	0.0125	0.0125
Weight per foot, pounds.....	37.0	......	31.4	......	21.0
Barrels cement per foot......	0.405	......	0.342	......	0.310
Weight joint rings, pounds...	71.0	......	91.0	......	70.0
,, ,, ,, per foot ..	8.3	......	10.7	......	8.2
Cost per linear foot of:					
Sheets..................	$1.26	$1.02	$0.73	$0.86	$0.58
Making pipe.............	0.28	0.46	0.23	0.39	0.26
Joint castings...........	0.23	0.23	0.21	0.29	0·23
Cement.................	0.57	0.40	0.33	0.34	0.31
Gates, valves, etc........	0.05	0.04	0.08	0.07	0.06
Labor and laying.........	1.48*	2.22	0.53	0.80	1.25
Sum................	$3.87	$4.37	$2.11	$2.75	$2.69
Total actual cost, including all special obstacles, engineering and contingencies	$3.86	.....	$2.39	.....	.....
Ratio of total cost to sum of items above given.........	1.00	.....	1.13	.....	$1.06
Total estimated cost, including engineering and contingencies................	.....	$4.37	.....	$3.10	2.85
Fair value to use is estimate on which 14 per cent. for engineering and contingencies is to be added........	.....	3.85	.....	2.72	2.50

* The contract price at ordinary depths of cut, and exclusive of rock, was 70 cents per linear foot. The difference, 78 cents per foot, represents the additional allowances for extra depth and for rock and for tunnel, and for all contingencies because of the character of the ground. These additional costs would naturally be somewhat higher on the 26-inch line than on the 24-inch line, and the route of the 20-inch line covers substantially the same space as that occupied by both the 26-inch and 24-inch lines.

Pitometer gagings were made of the mains from Sebago Lake to the city of Portland covering a period of a little over one month, March, 1908. From these the following coefficients of discharge applicable to the Hazen-Williams hydraulic formula were determined:

26-inch, $c=100$,
24-inch, $c=100$,
20-inch, $c=\ 90$,

but there was reason to believe that there was an unknown cross connection from the 26-inch and 24-inch compound high-service line to the 20-inch low-service pipe line. This makes it *probable that the actual coefficient (for Hazen-Williams' formula) was about* c = 95 *for all three of these pipe lines.*

This coefficient is as low as would be expected from cast-iron pipe of like age and was a surprise to the engineers, who had looked for a coefficient of from 110 to 120. The low value is probably to be accounted for, in part at least, by the internal restrictions at the pipe joints, which were plastered inside after laying, and to a slightly smaller *actual* than nominal diameter (the coefficient being figured upon the nominal pipe diameter).

Revere and Saugus, Mass. (Information from Supt. A. S. Burnham.)

The town of Revere had a population of 12 659 in 1905. The town of Saugus had a population of 6 253 in 1905. The water-works system was installed in 1884, the main pipe being cement lined. In 1894 further employment of this kind of pipe was abandoned, the reason given by the superintendent being that the price of cast-iron pipe sunk to a point where competition with cement-lined pipe was possible.

The original works were controlled by a water company and were taken over by the town in 1905. No records previous to this time were obtainable from the present management. At the present time there are about 18 miles of cement-lined pipe ranging in size from 4 inches to 16 inches, and 19 miles of cast-iron pipe.

The superintendent states that he remembers a case about fourteen years ago, the exact date being forgotten, when lightning struck a house and followed the service pipe into the main and disrupted the joints of five or six lengths of pipe.

A rough summary of the repair account for two years, taken from the books of the Water Department, is given in the following table:

	No. of Leaks.	Cost of Repairs.	Miles of Pipe.	Cost of Repairs per Mile of Pipe.
Ten Months of 1905.				
Cement-Lined Pipe...........	19	$245.00	18	$13.60
Cast-Iron Pipe...............	6	37.00	18	2.05
For the Year 1906.				
Cement-Lined Pipe...........	9	$63.00	18	$3.50
Cast-Iron Pipe...............	4	14.00	19	0.74

Average pressure, 70 pounds. Average age of pipe, 19 years.

Riverton, N. J. (Information received from Mr. Howard Parry, superintendent of the Riverton and Palmyra Water Company.)

"We have used the Phipps patent cement pipe, as manufactured by the American Pipe Manufacturing Company of Philadelphia, Penn., nearly exclusively.

"We have about twenty-two miles of pipe in our system — it is all cement (except about two miles of 4-inch cast-iron) that was put in on the outskirts of our town, and paid for largely by the consumers we were supplying, iron being down in price to less than one cent a pound at that time. Our company was incorporated in 1888, and the works were built in 1889. The cement pipes, 4-inch, 6-inch and 8-inch, put down in 1889, are just as good now as when first laid; the 16-inch, put in recently, seem also to be O.K. We have had occasion to put in two fire hydrants within the last ten days, which necessitated cutting the pipe to put in the specials. We found this cement pipe in perfect condition, perfectly smooth inside. No filling up. Same diameter as when laid. The cement gets harder and better with age — as our engineer reports when drilling for new taps. We have no leaks to speak of. I do not believe they will average one a year on our whole system, after the water has been turned on and in service. On some of our new extensions there have been a few leaks from imperfect joints, which developed when the water was turned on, but after they were repaired, we have had no further trouble with them. I think a good deal of this trouble was caused by an intemperate joint maker. We were told by the 'cast-iron men' the life of our cement pipe would be about fifteen years; they have been in now eighteen years, and are

just as good, if not better, than when laid, at the same price per foot. We would not lay another foot of cast-iron pipe. I think the Phipps cement pipes are like wine, they get better with age,— the older the better. I do not know how they will answer under high pressure. Our pressure is low, — from 20 to 50 pounds, standpipe pressure, at different parts of our system, — but I should think they could be made to stand any pressure needed.

"All complaints from rusty water are from those consumers using water from the iron pipes. The cement pipe delivers the water to the consumer just as clear and pure as when it is pumped. We have as good a pipe as can be laid, and know of none better."

Springfield, Mass. (Information from Elbert E. Lockridge, chief engineer.)

Letter addressed to Mr. E. V. French, February 10, 1908.

"Your letter of February 5, 1908, is at hand. In regard to the cement-lined pipe in Ludlow and this city, I am sending you a copy of the report of the Board of Water Commissioners for 1876. This is a report on the work done in 1875. I call your attention particularly to page 23, in which a discussion on the value of cement-lined pipe is entered into. The arguments as they appear at that time are well set forth between pages 23 and 29. This is included in Mr. Phineas Ball's report.

"On page 29 you will see some records of some of Worcester's experience, and also a statement of the way cement-lined pipe should be laid. On page 45 you will find a table which shows the size and amount of pipe laid each year. You will see in this table that the 24-inch main line was laid in 1874, with but a few lengths in 1875. The general impression had been, and, in fact, it was the impression which I had, that most of this was laid in 1875. However, this probably is conclusive.

"On pages 46 and 47 is a list of the cement pipe laid in 1875, by streets.

"It is but fair to state that this year we are planning to replace a portion of these pipes laid in that year. Some of them have given very satisfactory service throughout the entire time. Others have not and have been the cause of breaks which tore up the pavement, as was the case of the Locust Street break two or three weeks ago, which did considerable damage to the street car company as well.

In regard to the 24-inch main line from Ludlow to this city, I have been told by those who remember its laying that a considerable portion of it at the reservoir end had to be taken up and

relaid with cast iron the first year. I have been told that the reasons for this were partly from settling, causing breaking, and I have also wondered if it was not practically due to the mixture of the cement, as you will note in this statement: 'During the past year they had used only neat cement, while formerly some sand had been mixed with the cement.' Since this replacing, the first year after the pipe was laid, I believe there have been no repairs, or if any, very slight repairs on the main pipe. We have believed that the trouble with cement-lined pipe was largely due to breaking and chipping of the cement from the inside surface when the tap was made, thus exposing the wrought iron to the elements.

"I am also sending you a copy of the 1878 report, which is chiefly valuable as indicating the kind of pipe being laid. You will notice on the list on page 21 but one cement pipe listed, and I have been told that following this date no cement-lined pipe has been laid in the city. You will note from the last report the mileage still remaining."

See also Phineas Ball's report quoted on pages 3–9.

WALTHAM, MASS. (Information from Supt. Leroy Brown and Ex-Supt. George E. Winslow.)

Waltham had a population in 1905 of 26 282. Water works were constructed in 1872, the mains being cement-lined pipe. In 1887 the further use of this pipe was practically abandoned, and since that time substitutions have been made until at the present time there is left only about one mile of cement pipe. In 1887 there were about twenty miles of cement-lined pipe, ranging in size from 4 inches to 16 inches.

The reason given by Mr. Brown for giving up the use of this pipe was leaks in the joints, also trouble in making connections and care necessary in opening and shutting gates to prevent water hammer, which is liable to cause breaks.

On July 4, 1879, lightning caused the destruction of 300 feet of 6-inch pipe, cast iron being substituted at a cost of $263. July 12, 1883, lightning again caused a small leak and it was repaired at a cost of $20. August 3, 1889, 32 feet of 4-inch pipe was destroyed, and on August 12, 1891, 1 070 feet of 6-inch pipe was destroyed by lightning.

The Waltham report for 1895 contains reference to electrolysis in connection with the cement-lined pipe, and states that several

pieces dug up near the electric-car tracks were badly pitted and that the pipe was rendered practically worthless.

Year.	No. of Leaks in Cement-Lined Pipe.	Total No. of Leaks.	Cost of Repairs on Cement-Lined Pipe.	Cost per Leak.	Cost per Mile.
1883	13	19	$232.00	$17.84	$11.60
1884	15	27	245.00	16.33	12.25
1885	6	13	45.00	7.50	2.25
1886	7	12	400.00	57.15	20.00
1887	5	12	154.00	30.80	7.70
1888	8	10	179.00	22.38	8.95
1891	37	41	1092.00	29.52	54.60
Average ..	13	19.1	$353.30	$25.79	$16.76

During this period there were about twenty miles of cement-lined pipe in the system.

The large number of leaks noted in 1891 was partly due to the beginning of construction of a sewerage system in the city. Laborers in digging trenches for sewers caused damage to the water pipes. It should be noted that the cost of repairs given in the above table generally includes the substitution of cast-iron for the old cement-lined pipe.

Watertown, Mass. (Information from former Supt. John H. Perkins.)

Watertown had in 1905 a population of 11 202. Water works were constructed in 1884, about fourteen miles of cement-lined main pipe, from four to fourteen inches in diameter, being laid. Since about 1890 no cement-lined pipe has been laid. All pipe construction since that time has been of cast iron. Mr. Perkins claimed that the reason for making the change was that cement-lined pipe could not be bought after 1890 in the market, and as they had no conveniences for making pipe themselves, cast iron was substituted. Since the supply was introduced about one-half mile of cement-lined pipe has been removed and replaced by cast-iron. Some of the cement-lined pipe, however, is still in excellent condition. A piece of 6-inch pipe on exhibition in the office of the

water works, which was stated to have been in the ground for eighteen years before removal, is in first-class condition.

The number of leaks in the whole system reported during 1906 was five, and it is stated that the cost of repairs is only $3.05 per mile. This, of course, was on the total length of main in use, 37 miles, of which about fourteen are of cement-lined pipe. At the office of the water works it is stated that great care is exercised in opening and shutting gates to prevent water hammer, as this has caused leaks at various times. It is also stated that pipes have been particularly liable to deterioration where they are near the electric railroad tracks, presumably due to electrolysis.

WILDWOOD, N. J. (Information received from Mr. Clarence Miller, superintendent of the Wildwood Water Works Company.)

"I have had some experience along this line, having had charge of the present plant for about five years and was also connected with the same company at Phœnixville, Penn., for some time. The pipe we use is manufactured by the American Pipe Manufacturing Company, of Philadelphia, and is known as cement-lined pipe, — same being constructed as follows: Outside covering of jacket iron about 1-32 inch in thickness, then there is a layer of cement about 1 inch in thickness; inside of this there is another covering of iron about 1-16 inch in thickness, and then this is lined on the inside with about ¾ of an inch of cement. The inside lining of cement is of Hoffman Rosendale, the outer layer of cement being of the best grade of Portland. This makes a very nice pipe in appearance and it is capable of carrying anything up to about 125 pounds pressure to the square inch. The connections or joints on this pipe are comprised of a male and female ring which fit neatly together, this being covered with cement, then a slip sleeve is used, which holds the cement in place, and then an outside covering of cement is used to keep the sleeve from corroding or rusting from the dampness. It is necessary, when laying this kind of pipe, to let the joints set about four weeks before turning on the pressure, so as to insure their being dry and hard. In tapping this kind of water main, we use a steel girth with a cast-iron saddle (same being drilled and tapped to suit the specified size of connection); under this saddle we use a small piece of rainbow packing about ⅛ inch in thickness, which acts as a gasket and makes a water-tight joint. The corporation is connected to the saddle and then a tapping machine especially constructed for this make of pipe is used in drilling

the pipe. For cleanliness, I have never found anything in the pipe construction to equal it, as it is the same as a stone jar on the inside and there is never any corrosion of or deposit upon the pipe. I have removed some 4-inch pipe that has been in service for over eleven years, and it was just as clean as the day it was laid (same was removed to be replaced with a larger size) and did not show any defects from long using."

Woburn, Mass. (Information from the registrar.)

Woburn had a population in 1905 of 14 402. A water-works system was installed in 1873. The use of cement-lined pipe was given up in 1899, but no work has as yet been done toward the replacement of cement lined with cast iron, new construction only being of cast iron. In 1874 there were 24 miles of cement-lined pipe, and at the present time there are about fifty-one miles together of cement-lined pipe with some five miles of cast-iron

Woburn, Mass.

Year.	No. of Leaks.	Miles of Pipe.	Leaks per Mile of Pipe.	Cost of Repairs.	Cost per Leak.	Cost of Repairs per Mile.
1879–1886	51(av.)	38(av.)	1.34	......	......	......
1890	23	45	0.51	......	......	......
1891	9	47	0.19	$120.00	$13.30	$2.50
1892	30	49	0.61	334.00	11.10	6.80
1893	24	49	0.49	373.00	15.50	7.60
1894	25	50	0.50	263.00	10.50	5.30
1895	68	51	1.33	601.00	8.80	11.80
1896	57	51	1.12	646.00	11.30	12.70
1897	92	51	1.80	1 199.00	13.00	23.50
1898	32	51	0.63	414.00	12.90	8.10
1899	34	52	0.65	422.00	12.40	8.10
1900	50	54	0.93	752.00	15.00	13.90
1901	43	54	0.80	741.00	17 20	13.70
1902	35	54	0.65	832.00	23.80	15.40
1903	34	55	0.62	801.00	23.60	14.60
1904	59	55	1.07	2 318.00	39.30	42.20
1905	53	55	0.96	1 164.00	22.00	21.20
1906	45	57	0.79	1 084.00	24.10	19.00
Average, 1897–1906	47.7	53.8	0.89	$972.70	$20.40	$18.08

pipe. The average age of the pipe is about twenty-three years. The average pressure in the city is 70 pounds.

Almost every annual report contains references to breaks caused by lightning. In 1886 about a mile of pipe was so damaged by this cause that reconstruction was recommended. From 1884 to the present time some two hundred leaks have been attributed to lightning. Leaks are attributed principally to lightning, rust, bad joints, water hammer and thin lining.

The number of leaks and the cost of annual repairs are shown in the table on page 55.

OTHER WROUGHT-IRON CEMENT-LINED PIPE SYSTEMS.

Mr. J. W. Ledoux, chief engineer of the American Pipe Manufacturing Company, of Philadelphia, who has had much experience in the installation of wrought-iron cement-lined pipe systems, has kindly furnished the writer with the following list of works for which a considerable proportion if not the entire pipe system has been built of cement-lined pipe, and it was the intention of the writer to communicate with these water works in regard to their experience with this pipe, but lack of time and space have alike prevented his doing so, though he is still in hopes that Mr. Ledoux himself will contribute to the discussion of this paper.

Springfield Water Company	Lansdown, Penn.
North Springfield Water Company . .	Bryn Mawr, Penn.
East Jersey Coast Water Company . .	West Asbury Park, N. J.
Wildwood Water Company	Wildwood, N. J.
Moorestown Water Works	Moorestown, N. J.
Riverton Water Company	Riverton, N. J.
Norfolk County Water Company . . .	Norfolk, Va.
Sumter Water Company	Sumter, S. C.
Paris Mountain Water Company	Greenville, S. C.
Tallahassee Water Company	Tallahassee, Fla.
Milledgeville Water Company	Milledgeville, Ga.
Opelika Water Company	Opelika, Ala.
LaGrange Water Company	LaGrange, Ga.
Derry Water Company	Derry, Penn.
Skaneateles Water Company	Skaneateles, N. Y.
Jordan Water Works	Jordan, N. Y.

Statistics Relative to the Use of Cement-Lined Main Pipe.

Compiled from interviews and from reports. Some figures necessarily approximate only.

City or Town.	Population in 1905.	Works Built.	Length of C. L. Pipe in Miles. 1886.	1906.	Total Miles Extension. 1886–1906.	Extensions of C. L. Abandoned.	Replacement Begun.	Reason Given for Abandonment.	Approx. Age of Pipe when Replacement Began.	Pressure Lbs. per Square Inch.	Average Annual Cost of Making Repairs per Mile of C. L. Pipe.	Trouble from Lightning.
Attleboro, Mass.	12 702	1873	16	None	About 36	1880	1898	Trouble making connections	25 yrs.	65–100	...	1 accident
Arlington, Mass.	9 668	1872	About 12	4	...	1872	About 1895	...	23 yrs.	50–90	...	2 accidents; 1 cost $974.
Brockton, Mass.	47 494	1880	3	3	69	...	...	...	...	50	...	...
Beverly, Mass.	15 223	1869	48	32	Over 19	1894	About 1895	Poor condition of old pipe	26 yrs.	72	$49.00 (1899–1906)	3 000 ft. required replacem't
Burlington, Vt.	18 640*	1867	19	4	11	...	...	...	?	70–85	...	...
Chelsea, Mass.	37 289	1867	23	None	...	1875	1875	Leaks caused by making connections	8 yrs.	50–75	...	1 accident
Concord, Mass.	5 421	1874	21	21	12	1888	Not begun	...	...	...	$5.00	Some trouble
Concord, N. H.	19 632*	1872	Over 30	18	34	1887	1898	Breaks from rust	26 yrs.	45–75	$18.00 (1900–06)	400 ft. replaced
Fitchburg, Mass.	33 021	1873	17	None	40	1877	1883	...	10 yrs.	75–165	...	...
Gloucester, Mass.	26 010	1884	...	19	...	1896	1896	Poor condition	12 yrs.	15–75	...	Considerable trouble
Hartford, Conn.	79 850*	1857	15	3	...	1884	1886	Frequent breaks; expense of repairs	29 yrs.	...	...	...
Lee	3 972	1883	10	10	...	1883	Not begun	...	...	...	$20.00 about	1892 damaged 2 000 ft.
Lynn, Mass.	...	1871	63	32	30	1884	1890	...	19 yrs.	...	...	...
Malden, Mass.	38 037	1870	About 45	20	35	1890	1892	...	22 yrs.	65	$30.00 about	Considerable
Manchester, N. H.	56 987*	1872	27	4	62	1877	1877	Trouble in making repairs	5 yrs.	60	...	1 accident
New London, Conn.	17 548*	1871	22	About 8	39	1889	1889	...	18 yrs.	60–75	...	1 stroke caused damage $940
Pittsfield, Mass.	25 001	1855	3	None	...	...	...	Freezing. Poor workmanship	?	60	...	Some trouble
Plymouth, Mass†	11 119	1885	23	47	24	‡	...	...	...	50	$11.00 (1902–6)	...
Revere and Saugus.	{ 12 659 } { 6 253 }	1884	About 18	18	...	1894	Not begun	Lessened cost of cast iron	...	70	...	1 accident
Springfield, Mass.	73 540	1864	48	33	80	1882	1886	...	22 yrs.	30–120	$10.00 (1900–6)	...
Waltham, Mass.	26 282	1872	20	1	21	1887	1887	Leaks in joints; trouble in making connections	15 yrs.	50–70	$17.00 (1883–91)	1 400 ft. replaced; 4 accidents
Watertown, Mass.	11 202	1884	14	13	...	1890	Not begun	Cement pipe could not be obtained; trouble from electrolysis	13 yrs.	...	...	...
Whitman, Mass.	6 521	1883	12	12	12	1883	Not begun	No appliances for making C. L.; C. I. more convenient	...	65	Very small	None
Woburn, Mass.	14 402	1873	39	51	18	1899	Not begun	Lightning, rust, bad joints, thin lining	...	70–75	$14.00 (1891–6)	200 leaks; 5 000 ft. replaced
Worcester, Mass.	128 135	1845	41	None	97	1880	About 1880	...	35 yrs.	70–150	$52.00 (1884–86)	...

* 1900. † Since 1900, Phipps patent. ‡ Still in use.

RESULTS OF INQUIRY UPON EXPERIENCE WITH WROUGHT-IRON CEMENT-LINED PIPE IN NEW ENGLAND.

In order to bring into convenient and comparable form the results of experience in New England with pipe of this character a parallel column is subjoined giving the views expressed in 1888 by water-works superintendents in different communities as typified by the data contained in the *Engineering News* article above referred to, and the views developed by the writer twenty years later, that is, in the year 1908, first, as applied to pipe distribution systems, and second, as to supply mains; and in a third table are condensed the results of the writer's inquiry in 1908.

Experience with and Opinions upon Wrought-Iron Cement-Lined Pipe in Various Cities up to the Year 1888 and in the Year 1908.

1888.	1908.
Boston, Mass.	
Gave it up on account of rusting and bursting.	Using cast-iron pipe only.
Brockton, Mass.	
Reports cement-lined pipe all right and no leaks.	No distribution pipe. Only three miles supply pipe.
Brooklyn, N. Y.	
Used it from 1859 to 1884 and gave it up as unserviceable.	Using cast-iron pipe only.
Cambridge, Mass.	
None laid for fifteen years.	Using cast-iron and steel pipe.
Chelsea, Mass.	
Used some such pipe for twenty-one years and its condition is fairly good, but cast-iron pipe was found to be more reliable and economical.	None remains. Using cast-iron only.
Concord, N. H.	
Has used cement pipe for sixteen years. It is in good condition.	Began replacement in 1898. Fourteen out of twenty-eight miles in 1887 now in use.
Fitchburg, Mass.	
Used it from fourteen to seventeen years, but gave it up because repairs cost more than the change to cast-iron pipe.	Using cast-iron pipe.

	1888.	*1908.*
Hartford, Conn.	Has twelve miles of cement-lined pipe and has used it for twenty-five years, but it has given much trouble from breaks.	Using cast-iron pipe.
Malden, Mass.	Laid some twenty years ago and is replacing it with cast-iron.	Using cast-iron pipe.
Manchester, N. H.	Used it for fifteen years, but is not laying any more on account of leaks and breaks.	Cast-iron pipe.
Meriden, Conn.	Has used it since 1869. Condition poor.	Cast-iron pipe.
New Bedford, Mass.	Considers it unreliable.	Cast-iron pipe.
New Haven, Conn.	Considers it reliable and contemplates no change.	Cast-iron pipe.
New London, Conn.	Would on no account lay a large main of cement-lined pipe, and small mains only with the best of materials and workmanship.	Eight miles (out of twenty-two in 1886) remain.
Pittsfield, Mass.	Used it since 1855. Condition good so far as known.	None remains.
Plymouth, Mass.	Using cement-lined pipe exclusively.	Still using cement-lined pipe exclusively. Giving good satisfaction.
Portland, Me.	After twenty years' experience has taken all the cement-lined distribution pipe up because it could not stand the pressure. Supply mains in good condition.	Cast-iron pipe only for distribution system. Supply mains still in use, but new cast-iron pipe or steel mains will probably soon be laid.
Providence, R. I.	Considers the pipe treacherous.	Cast-iron pipe.
Salem, Mass.	In use for twenty years and considered good.	Appropriations recently made to replace cement-lined pipe with cast iron.

1888. *Somerville, Mass.* *1908.*

Eighty breaks a year. Using cast-iron pipe.

Waltham, Mass.

Reports that as pipe is beginning to rust no more of it will be laid. Only one mile of it remains.

Woburn, Mass.

Reports it perfect for pressure of sixty to ninety-five pounds. Does not contemplate change. In 1899 abandoned further extension work of cement-lined pipe in favor of cast-iron pipe.

Worcester, Mass.

Had a little in use for twelve to sixteen years, but the condition is poor, owing to frequent leaks. None remains.

REPORTS UPON CEMENT-LINED SUPPLY MAINS.

Brockton, Mass., has a 20-inch and 24-inch pipe, about 3 miles long, one half of it running through a country district, the remainder through one of the outlying streets of the city. The latter half of the main has numerous connections. The original pipe shell was dipped in hot asphaltum and rolled in cement and sand before being placed. The lower end of the main is under about 50 pounds pressure.

1908. Superintendent states that there has been no trouble to speak of with this main during the twenty-eight years of its existence.

Concord, Mass. *1908.* Has two 10-inch pipes, approximately $2\frac{1}{2}$ miles each in length, laid from Sandy Pond to the town, the first in the year 1874 and the second in the year 1883. Both pipes are still in active service and have given comparatively little trouble from leakage. The maximum static pressure is approximately 40 pounds.

Concord, N. H., in 1872 laid a 14-inch cement-lined main from Penacook Pond to the city. This main was about 2 miles long, laid largely through a country district, and was under a pressure of about 60 pounds per square inch.

1908. The work of relaying this pipe with cast iron was commenced in 1897 and completed in 1901.

In 1883 a low-service main 18 inches in diameter, about 2 miles long, was laid, and in 1887 a high-service main 14 inches in diame-

ter, about 2½ miles long, was laid, the latter being known as the Penacook extension.

1908. These two last-mentioned mains are said to have given no trouble up to the present time.

Manchester, N. H., has a main about 4 miles long, laid in 1872; part of this is between the pumps and the reservoir, the lower part being subjected to about 60 pounds pressure. This wrought-iron cement-lined pipe has cast-iron bells and lead joints.

1908. This pipe is still in use.

Plymouth, Mass., laid in 1855 a 10-inch main, about 3 miles long, the lower part under a pressure of approximately 50 pounds.

1908. This pipe is still in use and in good condition. A new 18-inch wrought-iron cement-lined supply main is being laid this year from the source of supply to the pumping station and thence to the town.

Portland, Me. A 20-inch wrought-iron cement-lined supply main about 15.2 miles long was laid from Sebago Lake to the city of Portland in the years 1868 to 1869. In the years 1875–9 a second wrought-iron cement-lined pipe supply main was laid from the lake to the city. The upper portion of this, approximately 3½ miles in length, was 26 inches in diameter; the lower portion, approximately 11.4 miles in length, was 24 inches in diameter. (In 1901 the construction of the third line from the lake of 30-inch *cast-iron pipe* was begun and has not yet been completed).

1908. These two wrought-iron cement-lined mains are still in active service, though the construction of a new steel pipe capable of supplying the entire demands of the city will probably be begun next year, in which case the wrought-iron cement-lined pipes will be held as reserves only. Although there has been more or less trouble from leakage, these mains have done good service.

Springfield, Mass., laid in 1874 a 24-inch main about 10½ miles long from Ludlow reservoir to the city.

1908. The engineer of the department states that he understands that a considerable portion of it was relaid during the first year after construction, but that since that time little or no repairs have been necessary.

As summed up in a word, wrought-iron cement-lined pipe has,

generally speaking, proved disadvantageous for water-works uses *in distribution pipe systems*, except in comparatively small communities where street excavations and underground disturbances are of comparatively rare or unusual occurrence and where the pressure upon the pipes has been of moderate amount.

In *conduit* or *supply pipe* service, wrought-iron cement-lined pipe has given much greater satisfaction and has made on the whole a good record for itself, except where the pressure has been great or the pipe has been liable to disturbance by reason of insecure foundation, neighboring excavations, etc.

ADVANTAGES AND DISADVANTAGES OF WROUGHT-IRON CEMENT-LINED PIPE, AS COMPARED WITH CAST-IRON PIPE.

The advantages and disadvantages of wrought-iron cement-lined pipe as compared with cast-iron pipe may be briefly summarized as follows:

Advantages.

1. Freedom from tuberculation, resulting in comparatively small loss in carrying capacity during the life of the pipe.
2. Reasonably high carrying capacity,— technically referred to as high coefficient of discharge,— though less than that of *new* cast-iron pipe.
3. Longevity and durability under favorable circumstances.
4. Lower first cost when compared with cast-iron pipe costing over twenty-seven dollars, or thereabouts, per ton.

Disadvantages.

1. Absolute and relatively greater dependence upon good materials and good work in the manufacture and laying of the pipe.
2. Greater danger of bad or slipshod work in use of cement-lined rather than of cast-iron pipe, particularly in wet trenches or in localities affording insecure foundations.
3. Greater cost than cast-iron pipe under average conditions. (The approximately comparable cost of cast-iron pipe being $27 per ton or thereabouts, and the average price of cast-iron pipe about $25.)

4. Unreliability and danger from bad foundations and nearby excavations made at any time after the completion of the pipe line.

5. Small factor of safety and consequent danger from water hammer, careless manipulation of gates, etc. (The usual factor of safety in wrought-iron cement-lined pipes has been from 3 to 4, in steel pipes from 4 to 5, and in cast-iron pipes from 12 to 15.)

6. Resulting lower limits of safe pressures. Desirable limit, in the opinion of the writer, 65 pounds per square inch; in the opinion of the chief engineer of the American Pipe Manufacturing Company, 100 pounds per square inch.

7. The carrying capacity or coefficient of discharge may not differ materially from that of old cast-iron pipe if the cement pipe is badly made or laid.

8. Danger from lightning and liability of more extended damage therefrom.

9. Difficulty in making watertight joints and connections.

10. Repairs not so easily, cheaply, quickly, or effectively made as for cast-iron pipe.

11. Difficulty in making service pipe connections and greater likelihood of leakage.

CARRYING CAPACITY.

There can be no doubt that the cement coating in the interior of a wrought-iron cement-lined pipe is more satisfactory than the coating of the cast iron, so far as its effect upon the quality of the water is concerned, though the difference may be, and perhaps generally is, practically insignificant. No coating has thus far been found for cast-iron pipe which does not under average conditions sooner or later permit tuberculation. The rapidity and amount of this tuberculation varies with the quality of the pipe coating. Any excrescence of this sort must unquestionably decrease the discharging capacity of the pipe line. This fact is recognized in the design of our cast-iron pipe systems by the adoption of a pipe size or diameter which shall cover this progressive loss in carrying capacity. In other words, the pipe is designed for future rather than for present conditions.

The chief claim of the wrought-iron cement-lined pipe advocates has always been the freedom from tuberculation and maintenance

of carrying capacity of pipe of this character, and it is probably true that the carrying capacity of wrought-iron cement-lined pipe decreases but slightly during the life of the pipe under ordinary conditions.

Comparatively little information has been published of the actual carrying capacities of wrought-iron cement-lined pipes. Without attempting a technical discussion upon this matter, it may suffice to refer to a few examples of recent gagings of pipe of this character. Hazen and Williams in their hydraulic tables quote a range of coefficients for use in the Hazen and Williams formula of the following amount:

Experimenter.	Diameter in Inches.	No. of Observations.	Range of Velocity in Feet. per Second.	Range of *c*. in H.-W. Formula.	Mean Value of *c*.
Fanning........	20	11	1.49–4.04	127–118	122 *
Bazin..........	31.50	10	2.78–6.60	148–144	146†

Remarks: * Cement-lined iron. † Experimental conduit.

But the writer is inclined to regard these values as distinctly too high under conditions in this country, so far as he has observed them, though he recognizes and regrets the existing lack of specific data upon this subject.

Pitometer gagings covering a period of four weeks upon the 20-inch and the compound 26–24-inch wrought-iron cement-lined water mains of the Portland Water Company conduit during the recent valuation proceedings indicate a coefficient of discharge in the Hazen and Williams formula (as has already been referred to on page 49) of $c = 95$, though it is probably true that had the pipe been true to nominal diameter the coefficient would have approximated $c = 98$.

Some recent and crude observations at Greensburg seem to indicate a value of approximately $c = 100$, but more accurate experiments with Venturi meters are soon to be made.

The coefficient of the Springfield, Mass., cement-lined pipe is believed to approximate $c = 110$.

Approximate gagings at Plymouth, Mass., indicate a value of $c = 103$ to $c = 109$.

As compared with these coefficients of discharge for wrought-iron cement-lined pipe for use in the Hazen and Williams formula,

the relative discharging capacity of cast-iron pipe may be said to be approximately as follows:

For *new* cast-iron pipe	$c = 130$–140.
For cast-iron pipe 25 years more or less *old*......	$c = 100$.

While it is true that the coefficient for old cast-iron pipe, thirty-five years or more in age, may be as low as $c = 90$ or even 80, it should be borne in mind that growth in population and hence in water consumption and other causes usually results in the construction of additional supply mains, considerably within the limits of this period, and in such cases the new main is often built sufficiently large to care for the entire consumption of the community without the assistance of the old main. For this reason, and inasmuch as the experience with the modern pipe coating has been comparatively short, it seems reasonable to make a comparison of carrying capacities upon the following basis:

For wrought-iron cement-lined pipe........	$c = 120$,
For *new* cast-iron pipe....................	$c = 130$,
For *old* cast-iron pipe.....................	$c = 100$,

referring by c to the coefficient of discharge to be used in the Hazen and Williams formula. (This formula has been used by the writer as one of the reliable hydraulic formulas now in common use, and as the *most convenient* one on account of its ready application through the Hazen and Williams slide rule.) But attention is called to the fact that in a number of wrought-iron cement-lined pipe lines the actual coefficient c, as based upon the nominal diameter of pipe, varies from $c = 95$ to $c = 110$, and the assumption of a value of $c = 110$ or even $c = 100$ is, therefore, believed to afford a much sounder basis of design than the assumption of the above coefficient of $c = 120$. The difference in the actual process of making pipe must result in far greater variation in internal diameters in cement-lined than in cast-iron pipes, and this is, therefore, an essential factor in design. In order to do full justice to the cement-lined pipe, however, the coefficient $c = 120$ has been assumed for it in the following discussion. If the true coefficient of discharge should be found to be less, in the light of further information, the following figures should be corrected in accordance therewith.

RELATIVE CARRYING CAPACITY OF WROUGHT-IRON CEMENT-LINED AND CAST-IRON PIPE.

The relative carrying capacity of wrought-iron cement-lined and cast-iron pipes, based upon the above stated coefficients of discharge (c = 120 for wrought-iron cement-lined pipe; c = 130 for new cast-iron pipe; c = 100 for old cast-iron pipe) as applied to the Hazen and Williams hydraulic formula, *is shown by the direct ratio between the assumed coefficients of discharge;* that is, upon the above assumptions, new cast-iron pipe will discharge one twelfth more than wrought-iron cement-lined pipe under equal heads, and old cast-iron pipe will discharge but ten twelfths as much as cement-lined pipe under like heads.

Or, to put the matter in a different way, the same discharge can be had in cast-iron and wrought-iron cement-lined pipes of like diameter with the different friction losses shown in the following tabulation:

COMPARATIVE FRICTION LOSSES IN CEMENT-LINED PIPE AND IN NEW AND OLD CAST-IRON PIPE.

Internal Diameter of Pipe.	Velocity in Feet per Second.	Discharge in Gallons per 24 Hours.	Friction Loss in Feet. Cement-Lined Pipe. $C = 120.$* Per 1,000 Feet.	Per Mile.	New Cast-Iron Pipe. $C = 130.$* Per 1,000 Feet.	Per Mile.	Old Cast-Iron Pipe. $C = 100.$* Per 1,000 Feet	Per Mile.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8-inch	1	226 000	0.6	3	0.55	3	0.96	5
	3	677 000	4.5	24	4.2	22	7.3	39
	5	1 127 000	11.6	61	10.8	57	18.9	100
12-inch	1	508 000	0.43	2	0.37	2	0.6	3
	3	1 523 000	3.3	17	2.8	15	4.6	24
	5	2 538 000	8.4	44	7.2	38	11.8	62
16-inch	1	902 000	0.31	2	0.26	1	0.42	2
	3	2 707 000	2.3	12	2.0	11	3.3	17
	5	4 512 000	6.0	32	5.2	27	8.4	44
20-inch	1	1 410 000	0.24	1	0.20	1	0.33	2
	3	4 230 000	1.8	10	1.56	8	2.5	13
	5	7 050 000	4.6	24	4.0	21	6.5	34

* For use in Hazen and Williams formula.

Or, if we figure (upon the above assumptions) the necessary diameter of an *old* cast-iron pipe system to give a discharge equal to that of a wrought-iron cement-lined pipe under like head or friction loss, we find the following approximate results, within a range of velocities of from 1 to 5 feet per second:

Internal Diameter of Wrought-Iron Cement-Lined Pipe. ($c=120$.)	Necessary Diameter of *Old* Cast-Iron Pipe for Equivalent Discharging Capacity under Equal Heads. ($c=100$.)	Increase in Diameter.
8-inch	8.8 inches	10.0%
12 „	12.8 „	10.7%
16 „	17.2 „	10.7%
20 „	21.4 „	10.7%

It appears, therefore, that under the assumed conditions (as to coefficient of discharge for use in Hazen and Williams formula, for cement-lined pipe, $c = 120$; for old cast-iron pipe, $c = 100$) the cast-iron pipe in order to have the same carrying capacity as the wrought-iron cement-lined pipe at the end of a period of twenty-five years, more or less, *must be 10 per cent. or thereabouts larger in diameter.*

The effect of this increase in diameter upon the relative cost of the pipe is discussed further on.

CEMENT LINING AS A PRESERVATIVE OF THE METAL.

Past experience with wrought-iron and steel pipes indicates the distinct superiority of the former metal for water-works pipe lines. Unfortunately, however, it is impossible at the present time to obtain wrought-iron sheets of large dimensions for conduit work. This has necessitated the use in these large mains of steel, and experience up to this time with various coatings for the steel has not been thoroughly satisfactory. This subject is beyond the limits of this paper, but it is interesting to note that experiments are now being made by the city of New York, and perhaps in other quarters, upon the feasibility of lining and encasing large steel conduits with a cement coating, in substitution for the different paints and materials used heretofore for coating steel conduits.

These latter-day developments, however, contemplate a use of the cement coating primarily for the purpose of preserving the

metal. rather than for securing watertightness, and the results will be watched with great interest.

RELATIVE COST OF CEMENT-LINED AND CAST-IRON PIPE.

In the subjoined table is presented a statement of the comparative cost of cement-lined and cast-iron pipe lines. The cast-iron pipe has been figured upon the approximate ruling average price of cast-iron pipe during the last twenty-five or thirty years, to wit, $25 per 2 000 pounds. The weight of pipe used is that of the New England Water Works Association standard Class A up to and including pipes of 8 inches in diameter, and Class B for pipes of from 10 to 24 inches in diameter. While these classes are somewhat lighter than have been used in city work, they certainly afford a much higher factor of safety than that ordinarily employed in designing cement-lined pipe, and they have been successfully used in many water works for pressures up to and even in excess of 100 (to 125) pounds per square inch. The total cost per foot of the cast-iron pipe furnished and laid is shown in column 6, and for convenience there is shown in column 7 the amount which should be added to make a comparison with Class C pipe of the New England Water Works Association.

The prices quoted for the wrought-iron cement-lined pipe in the case of the Plymouth works represent the actual cost of the pipe, exclusive of administration expenses of the department, and in the other cases the contract prices at which these pipes were laid. It is hoped that others who have used pipe of this character will contribute items of cost for comparison with the table on page 68.

In general it may be said that upon the assumed basis of cost of cast-iron pipe, $25 per ton, and the assumed classification, wrought-iron cement-lined pipe does not show any material saving in cost over cast-iron pipe, even when correction is made for the difference in carrying capacity between old cast-iron pipe and cement-lined pipe as referred to previously herein. The latter fact increases the total cost of the cast-iron pipe approximately 7 per cent. above the figures shown in column 6 of the table, as appears rom the following tabulation:

COMPARATIVE COST OF WROUGHT-IRON CEMENT-LINED AND CAST-IRON PIPE LINES.

Internal Diameter, Inches.	With Cast-Iron Pipe at $25.00 per 2,000 Pounds. Costs per Foot.						With Wrought-Iron Cement-Lined Pipe. Costs per Foot.					
	N. E. W.W.A. Class.	Assumed Weight per Foot.*	Pipe Cost per Foot.	Assumed Cost of Laying.	Total Cost.	For Class C Pipe add per Foot.	Plymouth, Mass.,† 1900–1907. Pipe.	Plymouth, Mass.,† 1900–1907. Laying.	Plymouth, Mass.,† 1900–1907. Total.	Greensburg, Pa., 1888. Total.	Concord, Mass., 1873.	Portland, Me.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
4	A	17	$0.21	$0.25	**$0.46**	$0.01	$0.33	$0.30	$0.63	$0.51	$0.76	....
6	A	28	0.35	0.27	**0.62**	0.02	0.38	0.45	0.83	0.66	1.02	....
8	A	40	0.50	0.30	**0.80**	0.06	0.50	0.50	1.00	0.92	1.22	....
10	B	57	0.71	0.34	**1.05**	0.05	0.66	0.77	1.43	1.17	1.57	....
12	B	72	0.90	0.40	**1.30**	0.06	0.89	0.79	1.68	1.53	....	....
14	B	91	1.14	0.45	**1.59**	0.08	1.13	0.43	1.56	1.85	....	....
16	B	110	1.38	0.51	**1.89**	0.10	1.24	0.88	2.12	1.80	....	....
18	B	129	1.62	0.58	**2.20**	0.14	1.41	0.83	2.24	....	....	....
20	B	149	1.86	0.64	**2.50**	0.16	....	....	....	....	....	....
24	B	195	2.44	0.80	**3.24**	0.27	....	....	....	....	....	$2.36‡
26	..	...	....	....	....	....	....	....	....	....	....	3.87§

* Allowing excess weight of approximately 2 per cent
† Plymouth labor, $2.00 for eight hours.
‡ $3.02 equivalent 1908 price.
§ $4.37 equivalent 1908 price.

Percentage to be Added to the Total Cost of Cast-Iron Pipe (Furnished and Laid) to Compensate for the Assumed Difference in Carrying Capacity between Cement-Lined Pipe and Old-Cast Iron Pipe.

Diameter Pipe. (1)	Pipe Cost per Foot. (2)	Total Cost per Foot. (3)	Add 10 per Cent. to Column 2. (4)	Resulting Total Cost per Foot. (5)	Increase in Total Cost Per Cent. (6)
8 inch,	$0.50	$0.80	$0.05	$0.85	5.9
12-inch,	0.90	1.30	0.09	1.39	6.9
16-inch,	1.38	1.89	0.14	2.03	7.4
20-inch,	1.86	2.50	0.19	2.69	7.6
					Say, 7.0%

If the ratio in carrying capacities of the cement-lined cast-iron pipe should be as 110 to 100, as has been found to be the case in some cement-lined supply mains, instead of as 120 to 100 as assumed above, the increase in diameter of pipe would be approximately 4 per cent. instead of 10 per cent., and the corresponding increase in total cost of pipe line in place approximately 3 per cent. instead of 7 per cent., and if the ratio should fall to 90 and 95 there would be no material difference in cost.

NECESSARY PRICE OF CAST-IRON PIPE TO MAKE COST OF CAST-IRON PIPE LINE EQUAL TO THE COST OF CEMENT-LINED PIPE LINE.

Data are lacking upon which to base a satisfactory estimate of the price per ton at which cast-iron pipe may be bought without making the cast-iron pipe line more expensive than one built of cement-lined pipe, even with due allowance for greater loss in carrying capacity with lapse of time. It seems probable, however, that this price must exceed $27 to $30 per ton of 2 000 pounds, and still leave the balance as regards reliability in favor of cast-iron pipe; while the average price of cast-iron pipe during the past twenty-five years, more or less, has been approximately $25 per ton.

AVERAGE PRICE OF CAST-IRON PIPE DURING THE LAST TWENTY-FIVE OR MORE YEARS.

It was stated above that the average price of cast-iron pipe for water-works uses during the past twenty-five or more years had been approximately $25 per net ton of 2 000 pounds. In this

connection the following figures may be of interest. It should be noted also that when cast-iron pipe is unreasonably high, extension work is usually undertaken only so far as is absolutely essential. For this reason, it is not fair to average the ruling prices of cast-iron pipe from year to year to determine the average cost of cast-iron pipe to water-works departments during any period of years. The actual average cost of all pipe bought is almost certain to be considerably less than the average ruling price of cast-iron pipe over a like period of years.

Boston, Mass. During the past thirty years covering a period from 1878 to 1907, inclusive, the city of Boston awarded contracts for cast-iron pipe amounting to 115 452 short tons, aggregating an approximate cost of $2 845 670. This is equivalent to an *average price* of $24.65 per ton of 2 000 pounds.

Portland, Me. The Portland and Standish Water Companies, supplying the city of Portland and environs, purchased in the thirty-nine year period from 1869 to 1907, both inclusive, a total of 19 105 net tons of pipe, at a total cost of approximately $484 270. This is equivalent to an average price of $25.35 per ton of 2 000 pounds.

St. Louis, Mo. From the statistics relating to the "prices paid for cast-iron pipe by St. Louis, Mo., during twenty years, compiled by Wm. H. Bryan, from data furnished by W. E. Rolfe, of the St. Louis Water Department," published in the *Municipal Journal and Engineer* of ——, 1908, have been obtained the following figures: total purchase of pipe, 128 269 tons of 2 000 pounds; approximate cost, $3 034 000, or an *average price per ton* during this *nineteen-year period* of $23.74. (Inasmuch as the quantities purchased during the year 1888 were not stated, it was impossible to determine the average price for twenty years.)

Providence, R. I. The average price paid by a water company in the vicinity of Providence, R. I., covering 1 826 tons of cast-iron pipe bought in the twenty-year period from 1886 to 1906, was *$25.43 per ton of 2 000 pounds.*

Chicago, Ill. The writer is unfortunately not able to give the actual average price paid by Chicago, but the following figures for the pipe purchased during the twelve-year period from 1885 to 1906 may be of some interest:

Year.	Total Miles.	Cost Cast-Iron Pipe (2000 Lbs.).
1895	1 612.3	$26.00
1896	1 691.2	23.00
1897	1 730.3	19.00
1898	1 801.2	25.00
1899	1 846.9	25.50
1900	1 872.0	25.50
1901	1 890.0	23.50
1902	1 918.7	28.00
1903	1 939.7	33.00
1904	1 978.2	30.00
1905	2 038.5	27.50
1906	2 073.2	30.00

(Quoted from *Engineering-Contracting*, July 24, 1908.)

SUMMARY OF CONCLUSIONS.

With due allowance for variation in individual cases, and the local conditions or circumstances surrounding them, the following conclusions seem justified:

1. *Advantages of cement-lined pipe as compared with cast-iron pipe.*

a. Freedom from tuberculation and resulting maintenance of carrying capacity.

b. Carrying capacity probably approximately that of cast-iron pipe fifteen to twenty-five years old. The coefficient of discharge to be used in the Hazen and Williams formula probably lies between $c = 100$ and $c = 120$, depending upon the care used in making the pipe and the excellence of its finish.

c. Longevity and durability under *favorable* circumstances.

d. The cost may show some advantage when cast-iron pipe reaches a price upwards of $27 to $30 per ton.

2. *Disadvantages of cement-lined pipe as compared with cast-iron pipe.*

a. Absolutely and relatively greater dependence upon good material and good work in all details of manufacture and laying of pipe.

b. Greater danger of bad or slipshod work in wet trenches and under conditions affording insecure foundations.

c. Greater cost under average market conditions.

d. Unreliability and danger from subsequent excavations adjacent to pipe line.

e. Small factor of safety and consequent danger from water hammer, careless manipulation of gates, etc. (The usual factor of safety of wrought-iron cement-lined pipes has been from 3 to 4; in steel pipes from 4 to 5, and in cast-iron pipes from 12 to 15, but the greater ductility of wrought-iron or steel as compared with cast-iron should be borne in mind in this comparison.)

f. Resulting comparatively low limit of safe pressures, 65 pounds per square inch, more or less.

g. The carrying capacity may not differ materially from that of old cast-iron pipe if the cement-lined pipe is badly made or laid, or is considerably smaller in actual than in nominal internal diameter.

h. Danger from lightning and liability of more extended damage from it.

i. Difficulty in making watertight joints and connections.

j. Repairs not so easily, cheaply, quickly, or effectively made as for cast-iron pipe.

k. Difficulty in making service pipe connections and greater likelihood of leakage.

3. Satisfactory data are lacking upon the carrying capacity of cement-lined pipes. It is believed that under favorable conditions the coefficient of discharge to be used in the Hazen and Williams formula is about $c = 120$, but under actual conditions this coefficient has been found, in several carefully observed cases, to lie between 95 and 110. Unless the conditions are definitely known, therefore, the use of a coefficient not exceeding $c = 100$ to $c = 110$ in the Hazen and Williams formula is recommended.

4. The relative carrying capacity of wrought-iron cement-lined pipe, new cast-iron pipe, and old cast-iron pipe, based upon assumed coefficients of discharge (for use in the Hazen and Williams formula) is in proportion to these coefficients of discharge:

$c=120$ for wrought-iron cement-lined pipe. (A safer figure would be $c=100$ to $c=110$.)

$c=130$ for new cast-iron pipe.

$c=100$ for old cast-iron pipe.

5. The comparative frictional losses based upon these assumptions are shown in the tabulation on page 65.

6. Upon the above assumptions the necessary increase in diameter of a cast-iron pipe line over that of a wrought-iron cement-lined pipe line that it may have the same discharging capacity at the end of a period of twenty-five years, more or less, should be approximately 10 per cent. If, however, the relative coefficients of discharge for cement-lined pipe, as compared with cast-iron pipe, are as 110 to 100 instead of 120 to 100, the necessary increase in diameter would be approximately 4 per cent.

7. The additional cost involved by the above-mentioned necessary increase in diameter of cast-iron pipe over cement-lined pipe, that they may have the same carrying capacity after a long period of years (based upon assumed relative coefficients of 120 for cement-lined and 100 for old cast-iron pipe), is approximately 7 per cent. If, however, the relative coefficients are as 110 to 100, the increase in cost would be but 3 per cent.

8. The cost of wrought-iron cement-lined pipe as compared with cast-iron pipe does not appear to be materially different and is slightly in favor of the cast-iron pipe up to diameters of 20 inches, more or less,— if a comparison be made upon the basis of use of classes A and B, Standard Specifications for Cast-Iron Pipe of the New England Water Works Association, which in the opinion of the writer is certainly as reliable as, and probably more reliable than, wrought-iron cement-lined pipe of the type heretofore used.

9. For purposes of comparison it seems reasonable to use an average price for cast-iron pipe of $25 per net ton of 2 000 pounds, inasmuch as this figure seems to approximate the average cost of cast-iron pipe for a period of twenty-five or more years in the past.

10. While it is true that many wrought-iron cement-lined pipe systems, built between the years 1870 and 1880 or thereabouts, are still in use, general experience seems to show that abandonment has begun within a period of twenty or twenty-five years after construction, though it is probably fair to say that this abandonment may have been due in some measure to the gradual increase in water pressures demanded of our water works by the change in height of buildings and the improved standards required

for fire protection. Certainly the general use of cement-lined pipe for water works purposes has been given up.

11. The average annual cost of making repairs to wrought-iron cement-lined pipe appears to have been as low as $10 per mile of pipe under favorable circumstances, and as high as $50 per mile of pipe, or even more, under less favorable circumstances.

12. Damage from lightning appears to have been a source of considerable expense in making repairs. The cost of these repairs is covered, however, in the above figures of annual cost of repairs per mile of pipe.

GENERAL CONCLUSION.

In conclusion, therefore, the writer is of the opinion that broadly speaking, it may fairly be said that:

1. Experience in this country with wrought-iron cement-lined pipe systems *for distribution purposes* has in general been adverse and has led to its replacement with cast-iron pipe,— except, perhaps, under conditions where the pressure does not materially exceed sixty-five pounds per square inch, and where there has been but little disturbance of the ground adjacent to the pipe trench which might cause settlement or other injury to the pipe line.

2. Experience in this country with wrought-iron cement-lined pipe systems *for supply mains* has been much more satisfactory than for pipe distribution systems, and many old wrought-iron cement-lined supply mains are still in active use and giving satisfactory and economical service, particularly under such conditions as are usual in the case of these supply mains,— light pressure, secure foundation, and private rights of way within which the pipes are located, resulting in little danger of disturbance.

3. It is still possible that economical means will hereafter be developed for lining steel or even cast-iron pipe in a similar manner to that so successfully now employed in lining service pipes with cement, which will result in a better pipe than any yet used. But such use of cement is likely to be limited to furnishing a durable coating rather than watertightness and added strength to the pipe.

The writer takes this opportunity of expressing his obligations to the various superintendents and other officials or employees

of the water works, who have so courteously and willingly contributed much of the information contained herein, without which this article would have been impossible.

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DISCUSSION.

MR. ARTHUR E. BLACKMER.* I don't think there is very much that I can add to what Mr. Metcalf has said. It is a fact that we have comparatively little trouble with our cement-lined pipe. We have about fifty miles in use now in sizes from four up to

* Superintendent Water Works, Plymouth, Mass.

eighteen inches, possibly half of which, or a little less, is of the old style of pipe, the Goodhue & Birnie, and approximately one half of the new Phipps patent, so-called. The pipe gives us practically no trouble under our pressures, which range from about thirty up to about seventy pounds as the maximum. We make the regular cement joint with a male and female ring and a sleeve, and our service-pipe connections are made by tapping in the corporations, and those, also, have been, so far, a source of very little trouble and expense. Down in Plymouth we look upon this pipe very favorably, though I am aware that it is not so regarded in most water-works communities. I don't know that I have anything more to say, but if there are any questions to be asked, I will be very glad to answer them if I can.

Mr. Robert S. Weston.* I would like to ask Mr. Metcalf or Mr. Blackmer if slime molds have ever been observed on the inside of the cement-lined pipe, which would have a tendency to reduce the discharge. I know that they occur within cement pipes and masonry conduits.

Mr. Blackmer. I have never discovered anything of that sort. We had occasion, recently, to take out a few lengths of 10-inch pipe, which have been in use since 1855, I think, and apparently they were as clean as when they were put in. There is one point in regard to Mr. Metcalf's coefficient of carrying capacity of the 10-inch pipe to which I should like to call attention, and that is that the pipe was an old pipe laid in 1855 and not one of the new style pipes.

Mr. Metcalf. In answer to Mr. Weston, I would say that I have seen evidence in two or three cases, certainly, of some growth of the sort he mentions on the pipe; but more often I have found the pipe, in the pieces which have been take out in cutting in hydrants or valves, or for one reason or another, substantially free from anything of that sort.

Mr. E. W. Kent.† I would like to ask Mr. Blackmer one question with reference to the table on page 68, column 9, where there seems to be a surprising difference in the cost of laying the pipe, a 6-inch pipe costing 45 cents a foot, and a 4-inch, 30 cents.

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* Sanitary Expert, Boston, Mass.

† Engineer and General Superintendent, Water Works, Newport, R. I.

Mr. Blackmer. That column was prepared by a clerk in the office. The cost of the 6-inch was an average of two lines which were unusually expensive lines to lay. They were laid rather deep, and we had a good deal of trouble with the main sewer, and a whole lot of trouble which increased the expense. That is not a fair average cost of the 6-inch line; it is too high.

Mr. R. C. P. Coggeshall.* I should like to ask Mr. Metcalf a question. We had originally about eight miles of cement pipe in our city, which was very poorly laid, and we used to have frequent breaks. Some years ago there was a remnant of it left, and at that time, when the electrolysis problem was coming up, I remember that Mr. Knudson, who made the examination in New Bedford, pointed at once to that remnant of the cement pipe and advised us to get it out as quickly as we could, saying that it was a good deal more liable to damage by electrolysis than cast-iron pipe. Now I would like to ask Mr. Metcalf if in the light of present knowledge, that is considered to be absolutely true.

Mr. Metcalf. You have asked me a very difficult question, Mr. Coggeshall, and I cannot answer you directly, because that question ought to be answered from experience and I do not think our present information is sufficiently definite to enable us to say whether that is true or not.

In discussing that very point with one of our prominent engineers who is laying some large steel mains at the present time, and is planning to coat them with cement for a portion of their length, partly on that account, he seemed to feel that the chances of trouble were less than with cast-iron mains. You have a good conductor throughout the entire length, and if the current gets on to the pipe it doesn't leave it at the joint and get on again. The trouble from electrolysis in a pipe line comes at the point where the current leaves the pipe; and in his case the question was as to whether he should make at certain points good connections for the current to leave the pipe, or whether he should simply take his chances on that and try to keep the pipe as dry as possible.

At the present time it seems to me that about all we can say is that the trouble from electrolysis is likely to be minimized if you can keep the pipe, in running it through the fields, dry rather than

* Superintendent Water Works, New Bedford, Mass.

in a moist condition, particularly in soils which carry a large amount of organic matter. Of course if you can get real wrought iron in place of steel you will find it more desirable, but the difficulty is that for these large pipes you cannot get large wrought-iron sheets; they are not manufactured. I think you can lay a 20-inch line, perhaps, of wrought-iron pipe; I do not think you can get a 30-inch without increasing the cost very seriously and the amount of riveting very largely.

Mr. Frank L. Fuller.* In cutting out some pipe at Winthrop to examine the pipe system we found that some of the pipes, in fact, I think all of them, had a coating of slime on the interior surface, and in that slime there were what you might call "wigglers," perhaps very small, something like what we find in stagnant water as the first stage of the mosquito. I have never seen them anywhere else and I didn't know whether they were peculiar to that system of piping or not. The pipe seemed to be in very good shape. A good deal of it had been laid quite a number of years, and as a general thing it was in very good shape and the interior was quite smooth.

The President. In partial reply to what Mr. Coggeshall has just asked, I would say that in Springfield we have had more trouble from electrolysis on service pipes attached to an old cement-lined pipe than anywhere else, but I had always supposed that the reason for that was because that pipe is in a street quite near to the power station, so that the current follows it in coming back to the generating source.

Mr. Metcalf. Is not that perhaps some evidence that the cement coating protected the wrought iron?

The President. Very likely, and the current left the service pipes. In some cases it had eaten up the corporation cocks entirely, so that we had to put a sleeve over the pipe to repair it.

Mr. Leonard C. Robinson.† We have about twenty miles of cement pipe mains. In 1905 there was a call for a high service for better fire protection, and it was decided to subject the wrought-iron and cement-lined mains to a series of hydraulic tests. A portable outfit was obtained, consisting of a single-acting Knowles

* Civil Engineer, Boston, Mass.

† Superintendent Water and Sewer Department, Concord, Mass.

pump 10 x 12 and steam boiler on rollers, and the mains were cut out section by section and then subjected to a test of from three quarters of an hour to an hour's steady pumping with a pressure of from eighty-five to one hundred pounds. Altogether there have been a little over twelve miles subjected to those tests. There have been 40 tests of pipe, and during that testing there were 25 leaks developed. The greater part of the leaks were on the 4-inch mains. Less than a mile of 8-inch pipe has been tested, and about two miles of 6-inch and something like nine miles of 4-inch pipe. The cause of the breaks in almost all cases was the detaching of the cement from the shell. Some ten years ago a system of sewers was installed in the center of the town, and a great deal of trouble with the pipe was caused by the settling of the pipe and the cement coating cracking and then the iron rusting. In one place three lengths were taken out where the pipe had settled so that the cement coating on the under side was entirely detached from the shell.

In the portion where there has been very little or no excavation in the streets, which comprises nearly one third of the length tested, there was only one break. Our pressure is comparatively light, something like forty-three pounds. The high-service system is now being installed, and the pressure will be increased to something like one hundred pounds, as Mr. Metcalf has spoken of, in times of fire. The original works were laid in 1874, and extensions were made with cement-lined pipe up to and including 1888. There was practically no difference in the number of breaks we got on the old mains and on the more recently laid.

Mr. Robert S. Weston. I would like to add a word regarding the theoretical considerations concerning electrolysis. It isn't the electricity which decomposes and dissolves the iron, but it is the products caused by the passage of electricity through something. Now from the purely theoretical standpoint it would be inconceivable to believe that electricity passing through the soluble products, or the dissolved part, of a cement coating, could attack iron, because all of the products which would be produced by electrolysis would preserve rather than attack the iron. On the other hand, of course, electricity passing from the pipe through water would decompose it into elements which would

attack the iron, especially in passing from iron through an acid soil, or through a soil containing a good deal of acid organic matter. It would seem that the conditions which affect the electrolysis of cement-lined pipe would be entirely independent of the cement coating, or else, if they did come in at all, they would act as protective agents rather than destructive influences.

THE PRESIDENT. Some of the most serious breaks we have had in Springfield since I have been connected with the works have been on this old-fashioned kind of cement-lined pipe; and we are now engaged in removing it as fast as we can. This year we have taken out some four or five miles of it, and next year probably as much more will be taken out, and so we shall go on until we have it all finally eliminated from the system. Practically the reason for doing it is that we are now engaged in remodeling our distribution system, and when that is finished we shall have only one service, which will be a high-pressure service. We now have two services, a high and a low pressure; the low-service system gives us about forty pounds pressure, and the new high-service system will carry about one hundred and forty pounds in the low districts and eighty pounds in the higher parts of the city.

One of the worst breaks we ever had was on a 12-inch cement-lined pipe, a little less than a year ago, in January, one of the most bitter cold mornings we had last winter. The department was called out at about five o'clock in the morning to shut off the street. The pipe was underneath the car tracks, and the water had followed along under the frost, which was about eighteen inches thick, to a point where it appeared about four or five hundred feet from where the break was; but before we could get the street entirely shut off the water succeeded in forcing its way up right over the break. We went to work immediately to repair the break, but it took us three days to repair the street for that four or five hundred feet in length, on account of the frost, and the car track was torn up so that cars couldn't run over it during that time. We got the pipe itself repaired in the course of twenty-four hours. We had to take out one whole length, of course, 7 feet, and put in another, and then when we turned the water on the next length had to come out of the ground just the same way. There were about eighteen hours of good solid work on one of the most

bitter cold days of last winter repairing a cement-lined pipe, and you can judge from that whether I should be in favor of installing cement-lined pipe in any system.

Mr. John C. Chase.* Mr. Metcalf's very exhaustive paper has left but little to be said. I trust he will not take serious offense, however, if I intimate that in my opinion what he has said will have very little weight in regard to the use or non-use of the pipe in the future. In a place where they have had the successful experience that they have had in Plymouth, I hardly think they would be strengthened in their belief in cement-lined pipe; but I doubt very much whether Plymouth's experience or anything which could possibly be said, would lead our friend Walker to lay another foot of cement-lined pipe. "Ephraim is joined to his idols; let him alone."

The high price of cast iron in the period from 1870 to 1875 was the cause of the boom, if I may use that term, in the use of a sheet-metal pipe. If the pipe had been properly, intelligently, and conscientiously laid, its life would have been a great deal longer, and it would have stood in great deal better favor with water-works people. I think the source of trouble with cement-lined pipe has been the fact that whenever it was laid by contract it was slighted wherever it could be. To give an idea of how quickly it began to come into disfavor, the city of Manchester, N. H., laid some forty miles, I think, in the period from 1871 to 1875, but abandoned its use as early as 1877.

Structurally I know of no reason why a sheet-metal, cement-lined pipe cannot be made that will answer all purposes and be entirely satisfactory, but it would be a pretty costly pipe to lay, and with the price of cast iron as it is at present and prospectively, the margin of difference would be such that it is a question whether it would be desirable to lay cast iron to make up for the expected lack or decrease in carrying capacity. And, as Mr. Dooley says, "There ye are."

Mr. Jasper A. Fitch.† Cement-lined pipe seems to be getting the black eye here, Mr. President. I haven't got much to say about it, but I am interested in a small plant in Manchester,

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* Consulting Engineer, Derry Village, N. H.

† Superintendent Water Company, Manchester, Conn.

Conn., owned by the Manchester Water Company, and we haven't anything but cement-lined pipe there. Our pressure through the main village is about seventy pounds, and we have about twelve miles of pipe, — a small plant. In three or four miles of that there is a pressure varying from 70 pounds to 100 pounds, and we are having very little trouble. The plant was established in 1889, the pipe has been in a little over nineteen years, and we have but very little trouble from breaks or joints. Sometimes we go through a year and there isn't a break at all, but occasionally we have a break the same as we would with iron pipe.

Our pipes are running in streets close by the trolley line, in some cases under it, but we never have had any trouble from electrolysis excepting in a case where an iron service pipe ran under the car tracks. In several cases we have had the iron service pipe eaten out by electrolysis, and it has had to be replaced, but there has been no trouble on the cement-lined pipe at all. We have had two cases where the gooseneck of brass was affected by electrolysis. As I say, our experience is not so great as that of some of you gentlemen, and we haven't got so many miles of pipe, and it hasn't been in so long, but we are well pleased with the working of it in our system.

Mr. J. C. Hammond, Jr.* Mr. Fitch is a neighbor of mine,— our towns join,— but our experience has been a little different. Our first aqueduct was laid in 1847 with cement pipe. We woke up along in 1866, and since then we have laid nothing but cast-iron pipe. That was before the days of the trolley, and I don't know much about the effect of electrolysis, but I know that when the current from the power house gets into a cement pipe it will go the whole length of it. I would recommend from my experience cement pipe for lightning rods, and for nothing else.

Mr. Edward V. French.† Mr. Metcalf has mentioned in his report some experience in Lynn, and I might just add a word bringing that up to date. We have taken out something over seven miles of cement pipe in the distribution system. There are plenty of breaks in it; it is something over twenty years old, I think all of it, and is giving us trouble regularly, so we are replacing it just as rapidly as possible. There are about seventeen miles

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* Secretary and Treasurer Rockville Water and Aqueduct Company, Rockville, Conn

† Vice-President and Engineer, Arkwright Mutual Fire Insurance Company, Boston.

left, which we hope to get out in the next few years. The pipe from some of the ponds down to the pumping station, running under a moderate head, perhaps less than fifty feet, has been in service for a great many years, and gives no trouble whatever,— following well the conclusions which Mr. Metcalf reaches.

We had one break this last summer in a 6-inch cement pipe, which tore up the street and threw large stones and a good deal of gravel up into the second and third stories of an adjoining tenement building, nearly covering up some of the people as they slept, and doing damage which cost the water department perhaps $1,500 to $1,800. So in Lynn, anyway, there is no more cement pipe going in at present.

The President. Perhaps I ought to have said, in connection with our experience in Springfield, that we have a 24-inch cement main pipe from our reservoir to the city, about twelve miles, and that main gives us less trouble than any cast-iron pipe we have in the city. We have had but one or two leaks on it since I have been connected with the works. So perhaps I ought to be on the fence as to whether to use cement-lined pipe or not.

I also ought to have said that the break I mentioned showed a good deal of evidence of electrolysis. There wasn't enough so that we could charge it to the railroad company. They presented us a bill for repairing their tracks, but the bill hasn't been paid yet and they haven't tried to enforce it, so I think it is perhaps just about six one way and half a dozen the other.

Mr. Edwin C. Brooks. In regard to what Mr. Metcalf said concerning cement being a protection against electrolysis, I would say that we have a great deal of electrolysis on service pipes, and that it occurs more frequently than anywhere else under conduits carrying feed wires.

Mr. Dean. I notice in the summary there is reference made two or three times to the use of cement-lined pipe in this country. I would like to ask whether cement-lined pipe is used in any other country.

Mr. Metcalf. I am not informed, Mr. Dean;. I don't know what the experience abroad is.

A Member. I would like to ask Mr. Blackmer or Mr. Metcalf what protects the pipe on a pump main. I have noticed

where the outside coating has been cut off that you will see it throb like a person breathing. What protects that pipe to keep the thin iron from rusting? The first time I noticed it was down in Mr. Blackmer's town, on a 16-inch main, I think it was, right close to pumping station. I remember I was making a connection for them, and I had a date in another town for that evening, and when they started up the pump to see whether it was all right, and I saw this throbbing, I thought I was done for. I don't know how long it lasted, but you could see every stroke of the pump on the shell, where the outside coating was taken off.

Mr. Blackmer. I don't know as I quite get the question. The new main has been laid only about a year, and some of the time there is direct pumping, but we haven't had any trouble whatever with it; we haven't had any leak to repair. I would like to ask Mr. Metcalf if he knows whether most of the data he has collected with regard to leaks and the cost of repairs, etc., are on the old style of Goodhue & Birnie pipe, or whether any of the data are on the newer style Phipps patent. I think it makes quite a little difference in the cost of maintenance and repairs what style of pipe has been installed.

Mr. Metcalf. Answering Mr. Blackmer's question, I think it is a fact — I don't know that I can state it absolutely as a fact, but I believe it to be a fact — that the leakage has been greater on the Goodhue & Birnie pipe than on the Phipps pipe, for the obvious reason that in the Phipps pipe the outer coating of cement is protected from injury in transportation and laying by this outer covering of steel or wrought iron, as the case may be, and by the fact that you are more likely on this account to get a substantial thickness of cement outside of your pipe at all points than you are in the case of the Goodhue & Birnie pipe, in which the casing or coating of cement is formed in the trench itself.

As to the question raised by the previous speaker, I take it that what he refers to is the breathing of the pipe, which I presume to be due to the surge of the water in the pipe line. That you would have in the case of wrought-iron cement-lined pipe in the same way that you would in the case of iron pipe or steel pipe. As to whether it would be sufficient to rupture the cement covering of the pipe or not, I suppose would depend upon its magnitude. I

should think you would be less likely to have serious trouble from it, perhaps, with a cement-coated pipe than with a steel pipe, — perhaps not less trouble, however, than you would have with a cast-iron pipe.

The effect of surge upon the pipe was referred to by Mr. Hazen a few days ago in speaking to me of some tests which he had just observed upon lock-bar pipe and riveted pipe. I think the lock-bar pipe had been put under 750 pounds pressure per square inch and had been tight. The riveted pipe had been put under a very high pressure,— I am not sure that it was over five hundred pounds, but it was very substantial pressure. Up to a certain point Mr. Hazen said the pipe was perfectly tight, but a few added pounds made it leak all the way along under the rivet heads and along the seams, so that the water simply poured out; it more than seeped out; it ran out of the joints. Yet, when that pressure was released, or reduced to a slightly lower point, the pipe was tight again. Mr. Hazen said it almost led one to believe that a riveted pipe of that sort furnished its own safety valve in long mains, so that when the pressure got intolerable, the pipe would open and let the water out.

Mr. Caldwell. May I say a word in answer to Mr. Dean's question? I think I can speak for the provinces of Ontario and Quebec, for I have covered that territory pretty thoroughly, and I do not know of their using any cement-lined pipe for mains in either of those provinces.

W. H. Richards (*by letter*).* If Mr. Metcalf's paper should encourage the use of cement-lined mains in any place where the conditions of a modern city prevail, except where some rare quality in the water precluded the use of cast iron, it would be most unfortunate.

The use of cement-lined pipe in large quantities prevailed about 1870 for reasons of economy (cast iron being very high). On this ground about twenty-three miles was laid under the direction of the writer between 1872 and 1884. While the number of leaks per mile was not excessive, the cost of repairing them, owing to their nature and the damage occasioned, was very great and is not indicated by their number. This pipe has been removed with the

* Engineer and Superintendent Water and Sewer Department, New London, Conn.

exception of 8 miles, and the cost of repairs per mile has dropped from $30.00 to $9.00.

The causes of failure in cement-lined pipe as observed by the writer were:

1. Lack of tightness of the shell. The porosity of the lining allows moisture to pass through to the shell, and, unless the shell is tight, to pass under the outside coating where the water, together with the air, corrodes the shell from the outside. This was overcome, and at the same time the strength was greatly increased, by using spiral riveted shells, the seams of which were filled with liquid wood pulp under pressure, after which the shell was dipped in asphalt and then lined with cement mortar made of carefully selected materials. Pipe constructed in this manner in 1883 is now in as good condition as when laid. Its cost, however, is much higher than cast iron.

2. Lack of strength to resist water-ram, etc. This was overcome as above, but at great cost.

3. Rigidity of joint which admits of no settlement.

4. Liability to injury from street excavation.

The first and second objections can be overcome by a large increase in cost and with no corresponding advantage over cast iron except in the rare cases where the nature of the water makes corrosion excessive.

It is impossible to attain even partial success with cement-lined mains without the most careful and painstaking inspection of the process of manufacture and the materials entering into it, and, as before stated, there is no corresponding advantage gained over cast iron.

In streets where excavations are freqeunt, as is the case in all of the larger towns and cities, cement-lined mains are entirely unsuitable.

I think that any manager of water works who has had twenty or more years of experience with cement-lined pipes and has kept out of an insane asylum will endorse my views.

Mr. Frank A. Barbour (*by letter*).* I have had no experience in laying cement-lined pipe, but have had considerable opportunity to investigate its condition after use of twenty years or more.

* Civil Engineer, Boston, Mass.

At the present time there are in Peabody about thirty miles of cement-lined pipe, varying in size from four to twelve inches in diameter. In 1895 there were thirty breaks, in 1905 sixty-five breaks, with a gradual increase between these years, while in 1906 and 1907, owing to the construction of sewers, the number of breaks rose to much higher figures. But little trouble has occurred at joints, the cause of breaks being generally corrosion from the outside. The leakage through this old cement-lined pipe is large and when the water pressure was raised 20 pounds, in 1904, the amount lost through the mains increased 200 000 gallons per day.

In Woburn, at the present time, there are about forty-five miles of cement-lined pipe, perhaps more than in any other place in this state. Recently an opportunity was afforded the writer to make an examination of this system for leakage, which has gradually increased to a point where it constitutes a large element in the cost of operation and is the principal cause of the present necessity for an increased supply. The leakage in the distribution system was studied by isolating small sections and measuring, by a meter, placed in a hose line stretched from a hydrant outside the district under examination to another hydrant inside this district, the water wasted either from the mains or by defective plumbing between the hours of 12 midnight and 4 A.M. If an abnormal quantity entered the isolated section, one street after another was shut off until the principal cause of the waste was located. To separate leakage from mains and from bad plumbing, the services in some cases were also shut off. In this way it was found that 90 per cent. of the leakage was located in 19 miles of the distribution system, the other 26 miles being in comparatively good condition. The greater part of the loss of water occurs in the smaller sized pipes — in one case a leakage of 100 000 gallons per twenty-four hours being found in 4 000 feet of 4-inch pipe. This is probably explained by the fact that lightning, to which most of the breaks in Woburn are attributed, has a greater effect on small than on large pipe, the larger pipe, apparently, because of the greater sectional metal, being capable of carrying off the electric charge with less disastrous results. The grounding of telephone wires on the service pipes is believed to add to the trouble due to lightning.

However, leakage is not confined to the smaller sizes, and in some sections of 12-inch pipe a loss equivalent to five or six gallons per linear foot was found. This might hold good for a certain length, while the next section of the same pipe would prove to be watertight. The explanation may lie in the varying character of the work originally done under different foreman, or to the effect of sewers subsequently constructed near the water pipes.

The depreciation of the cement-lined system in Woburn has reached the point where comprehensive replacement with cast iron must be undertaken in the near future, a fact which constitutes an interesting commentary on cement-lined pipe in general. In 1890 the superintendent of the Woburn works presented a paper to this Association extolling the merits of this type of conduit and claiming for it superiority over cast iron. The pipe had then been laid seventeen years and was considered entirely satisfactory by him. From the reports of the Water Department it appears that in 1890 there were 23 breaks; in 1894, 25 breaks; in 1896, 68 breaks (due to sewer construction); in 1900, 50 breaks; in 1905, 53 breaks; in 1906, 59 breaks; in 1907, 44 breaks; and in 1908, 71 breaks. Of the 50 breaks in 1900, 18 were charged to rust holes, 12 to joint leaks, and 13 to thin lining, 90 per cent. being on the 4- and 6-inch pipe. Of the 53 breaks in 1905, 29 are attributed to lightning, 11 to thin lining, 5 to rust, 3 to shutting hydrants too quickly, and 5 to joint leaks, again 90 per cent. being in the 4- and 6-inch pipe. It is evident that, after a use of twenty years, depreciation in Woburn became rapid, particularly since the date of installing the sewers.

Whether this class of pipe is subject to depreciation by electrolysis is perhaps debatable, but in Peabody, on those streets where the service pipes have been most rapidly eaten away by electrolytic action, the cement mains have on the outside the characteristic pitted appearance which such action develops in cast-iron mains, and such appearance is most marked on those streets where electric car tracks are located.

In the majority of breaks which the speaker has examined, the iron has been weakened by corrosion from the outside, the result of uneven placing of the outside layer of mortar, subsequent cracking of this layer, or too much sand in the mortar. In many

cases, however, breaks occur at points where in lining the pipe the cone has not been properly centered and the lining is consequently thin on one side. At these places scaling occurs and the exposed iron is reduced by rust until it cannot withstand the pressure.

Such disabilities as unevenness of covering of cement inside or out, too much sand in the mixture, or injury of the outside layer in laying are matters of workmanship rather than the unavoidable conditions necessarily incidental to this type of pipe. In such causes lies the explanation of the failure of much of the cement pipe laid thirty or forty years ago, but it is well to note that this cause of failure can be overcome, to some degree, by better workmanship — a result which has doubtless been accomplished in the more recent pipe of this type such as is used in Plymouth. In this respect, therefore, a fair criticism of this type of pipe is that for good results such care in manufacture and laying is required and such a cost necessary as compared with cast iron that under ordinary conditions it is neither economical nor worth while undertaking the responsibility of its installation.

Regardless of workmanship, however, there are faults inherent in this type of conduit which precludes its general use in distribution systems. The effects of lightning, the inability of the inelastic cement covering to accommodate itself to the continued pulsation of pumps, or abnormal water hammer in closing the hydrants, the inevitable injury to such pipe by the slightest movement of the ground during the construction of sewers, the liability to injury of the cement lining in tapping for service pipes, the gradually increasing leakage with the resulting cost in pumping system — all discount its use in distribution work. Whether gravity mains under light pressure with no service or hydrant connections may justifiably be laid with cement-lined pipe is largely a question of relative economy. I, therefore, agree with the author of the paper that if such pipe ought to be used at all its place is only for gravity supply mains and not in the distribution system.

The Association is to be congratulated on the comprehensive work done by Mr. Metcalf in making available for ready reference so much information in regard to cement-lined pipe. The paper is of value, however, as an historic record rather than in the possibility that much of this type of conduit will be used in the future.

THE WATER SUPPLIES OF NEW YORK STATE.

BY H. D. PEASE, M.D., DIRECTOR STATE HYGIENIC LABORATORY, ALBANY, N. Y.

[*Read November 11, 1908.*]

To visit one's native city is always interesting. When that city is Boston it becomes a feeling of stimulation and of pride; but to return and talk of one's work before an active and honored body of co-workers, such as the New England Water Works Association, should be the acme of satisfaction.

In talking to you of the water supplies of New York State I shall be obliged to limit the discussion to such aspects of the subject as have come particularly under the notice of the State Department of Health, and this will perforce exclude many matters of undoubted interest to you.

Thus I am not in a position to discuss the great work now being conducted in New York State towards the further development of the water supply of New York City. The problems involved in the construction and maintenance of the series of great public works, comprising the various water supply systems of New York City, are of such magnitude that they naturally exclude themselves from the consideration of a comparatively small department of state government, only a part of whose work lies in a similar direction.

I wish to discuss first the proper scope of the work of a state department or board of health in relation to the water supplies of its various political subdivisions or municipalities.

It appears to me that the fact should not be lost sight of that the departments or boards in question have as the main object of their existence the protection of the public health and the prevention of avoidable disease. Such departments or boards should not, therefore, in their dealings with water supplies, be expected, nor should they endeavor, to cover the fields of civil engineering, or to assume the judicial authority of the legislature and the

courts except in so far as it becomes necessary to do so in order to fulfill their main object.

Their chief function must always remain the protection of the public health and not the development of water-works engineering, nor the allotment of sources of water supply to various municipalities. Indeed, it has always seemed from this standpoint to be a misfortune that there has developed in so few states a department or departments of state administration, whose duty in part or in whole should be the accurate survey and determination of the water supply possibilities of the state and the various uses to which they could be economically directed.

No such department or departments have existed in New York state, although portions of such work have been performed by the departments of the state geologist, of the state engineer and surveyor, and from time to time by various water storage commissions now out of existence, and more recently by the State Water Supply Commission.

The work performed by all of these departments, except the latter, has related to the geographic, physiographic, and industrial conditions of the various watersheds, while the State Water Supply Commission was brought into being in 1905 for the purpose of providing for a fair and equitable distribution of the potable water resources of the state among the various municipalities. Some of these commissions have endeavored to bolster up their reasons for existence by attempting to absorb the functions of the State Department of Health in the investigation and regulation of the sanitary quality of water supplies, but up to this date their efforts have been practically futile.

The fact that the State Board of Health was the proper state department to be placed in charge of the protection of the public water supplies of New York was recognized by the legislature as early as 1885, only three years after the organization of the board. This recognition consisted in delegating to the board authority to make rules and regulations for the protection of public water supplies and their sources in the state.

This was excellent, but there were a number of conditions attached which have tended to prevent an overpowering desire on the part of municipalities and water companies to apply for the

formulation of such rules. The law provided that practically the entire burden of the enforcement of these rules and the whole expense of any changes or alterations required under their operation should fall on the municipality or water company benefited.

In the absence of a request to formulate these rules, the State Board of Health could gain little or nothing by making them, for the law provided that the inspections of the watershed for the violations of the rules were to be made by the water board or company whose supply was being benefited, and only upon their report to the State Board of Health could the latter take action under the law, nor could the board require that inspections be made by the water board or water company. This latter feature has been corrected by a recent amendment, which gives the state commissioner of health power to order regular and special inspections to be made.

As this law now stands, the locality to be benefited must apply to the department to make the rules for the protection of their water supply; this the department does after proper investigation; the rules are then approved by the local boards of health in the districts affected by them, and are finally published in the public press; the municipality must pay for the changes required by the rules; the local water company must make regular inspections to discover any violations of the rules and must serve notice upon the violator to correct them. If the violator refuses or neglects to comply with the rules, then the State Department of Health must be notified, and the latter must make an inspection to ascertain the true facts regarding the alleged violation; if this violation is found to exist, the department must then order the board of health of the district in which the violation occurs to convene and enforce obedience. If this local health board fails to perform this duty, then any person affected by the violation, from the State Department of Health down to the humble citizen, can begin action for the recovery of the damages and the issue of a restraining injunction against the violator.

At present sixty surface supplies are protected by such rules. There are still, however, about two hundred public surface supplies in New York state not so protected. Nevertheless this does not of necessity mean that all these latter supplies are not potable

waters of good sanitary quality, for a considerable number of them are subjected to more or less efficient filtration and are not much in need of the protection afforded by the department's rules.

For the purpose of stimulating local activity toward the correction of insanitary conditions on the watersheds of these unprotected water supplies and of creating a sentiment in favor of the formulation of rules, Dr. E. H. Porter, State Commissioner of Health, has during the past two years taken action along two lines.

First, he has ordered the State Hygienic Laboratory to undertake the bacteriological and chemical examination of samples of water collected by the inspectors of the department or laboratory from as many municipal supplies and at such intervals as the laboratory's resources would permit.

Second, and more recently, there has been ordered a sanitary survey by the Division of Sanitary Engineering, of a selected list of fifty of these unprotected water sources.

Acting under these orders, we have made in the hygienic laboratory examinations of 200 municipal water supplies during the last twelve months. Of these, 59 have been examined twice; 28, three times, and 20 have been subjected to repeated examinations at irregular intervals of an average of one month.

In the majority of instances the collection of the first samples was made personally by Mr. L. M. Wachter, the chief sanitary chemist, who at the same time also made a preliminary and rather general sanitary reconnaisance of the watersheds. In this work particular attention has been paid to municipalities having a high water-borne typhoid death-rate, and to filtration systems of the various types. This work has accomplished decided results in the way of the stimulation of the local authorities to undertake the correction of conditions dangerous to health.

It was as a result of this work that the city of Poughkeepsie was led to see clearly that the winter epidemics of typhoid fever during the years 1905–6 and 1907 were due to serious structural defects and deficiencies in the management of its historic slow sand filtration system. The application of the proper remedies brought about a most decided improvement in the typhoid situation during this past winter.

The following municipalities have been influenced to a greater

or less extent to take steps toward the elimination of dangerous conditions in their water supplies by the work of the state laboratory: Cohoes, which is now planning for a proper filtration system for its Mohawk River supply; Peekskill, which has plans at hand for a slow sand filtration system; Rensselaer, which was led to make extensive corrections in its mechanical gravity filters; Elmira, which has greatly improved the operative efficiency of its filter plant; and Niagara Falls, which is planning a new supply from comparatively unpolluted portions of the Niagara River.

As soon as sufficient data has been collected regarding some of the other questionable water supplies, the department will take vigorous steps towards the creation of a proper local public sentiment for the correction of the elements of danger existing in their water supply systems.

In addition to this work by the laboratory, special investigations have been conducted by the Division of Sanitary Engineering of the general sanitary conditions in those cities in which a high typhoid mortality has existed for a number of years. Among the cities thus investigated have been Ogdensburg, Niagara Falls, Elmira, Cohoes, Poughkeepsie, Newberg, Mt. Vernon, Dunkirk, and Corning.

Upon the completion of these reports the Commissioner of Health has followed the general plan of requesting a conference with the mayor and other officials and citizens of each city. At such meetings the situation, as found upon investigation, has been presented by the commissioner and his staff and thoroughly explained and discussed. In all instances where these investigations have shown that conditions dangerous to public health existed, improvements have been made or will soon be in effect. The pursuance of such a policy of conferring with the responsible local officials and prominent citizens on matters of public hygiene of local import has rarely failed to give excellent results.

In addition to these methods of direct attack against dangerous conditions in some municipal public water supplies, the director and the chemist of the hygienic laboratory or the other members of the Health Department's staff have investigated in the last two years twenty-five outbreaks of typhoid fever in cities and villages. Of these fifteen were found to have been due to the continuous or

accidental contamination of public water supplies, either by domestic sewage or directly by typhoid infected discharges. Upon the publication of the results of these investigations, but after the municipality has paid a great price for its gross negligence, the usual tardy process of correcting insanitary conditions has usually been inaugurated and some very great improvements in the public water supplies have been brought about. It is a disgrace to have to acknowledge the necessity for the operation at present of this most wasteful and extravagant method of educating the public to the essential requirements of a correct municipal hygiene.

Dr. Eugene H. Porter, the present State Commissioner of Health, saw early in his term of service that an educational program for the instruction of local health officers and physicians, regarding the essential principles of the protection, purification, and general control of public water supplies, was likely to be productive of good results. He, therefore, inaugurated a system of meetings, or sanitary institutes. These meetings have been held in various parts of the state, usually during the winter. The programs have consisted to a large extent of papers by the members of the department's staff on the various aspects of the character of the different types of water sources, the methods and nature of their pollution, the means of natural and artificial purification, and their inspection and protection. What might be called a hygienic exhibition, consisting, among other articles, of models of some of the types of water filtration systems and of sewage disposal plants, has been effectively utilized in these institutes. The attendance of health officers, physicians, and citizens has been excellent, and good results have been obtained. In addition to these institutes, the programs of the annual conferences of health officers have always contained one or more papers on these various aspects of water supply problems.

Three laboratory courses for health officers have been given at the State Hygienic Laboratory. In addition to instruction in other subjects, demonstrations of methods of analysis and examinations of water have been given, and conferences upon minor water supply problems have been held with the laboratory staff by those attending.

In addition to the activities just enumerated, and perhaps of greater importance in the protection of the public water supplies, is the enforcement of the act of 1903, which sought to prevent or regulate the pollution of the public waters in New York state. In brief, the law provided that after the date of its passage no sewage or other waste matter should be allowed to discharge into any of the waters of the state without the permission of the State Commissioner of Health. Important provisions, however, were inserted, allowing all discharges of such materials which were then taking place to continue unless those responsible for them desired to change or enlarge their sewerage system, in which case they became subject to the judgment of the Commissioner of Health in accordance with the strict provisions of the law.

The law was given special strength by requiring the immediate registration of all existing sewerage systems, and providing that no changes or alterations could be made until plans for the same should have been submitted to the State Commissioner of Health and approved by him. Suitable penalties and opportunities for obtaining restraining injunctions were provided for in the act.

Under this law marked progress has been made in the prevention of the pollution of New York waters. But few municipalities are so lacking in progress that changes in their sewerage systems do not become necessary, and in this way the State Commissioner of Health is gradually having the opportunity to pass upon the pollution of streams by public sewers. To acquire complete supervision over the long-existing private sewers and industrial waste discharge systems will require a longer period, as enlargements and changes in them are less frequent.

However, even if the Commissioner of Health had been given immediate authority to order the cessation of the pollution of public waters, a considerable time would have been necessary to bring about the elimination of all pollution of public waters in a state the size and age of New York. Work of this character requires the careful preparation of a definite program, based upon accurate knowledge of not only existing conditions, but of the past as well, together with a clear insight into future requirements.

It has been unfortunate, as I have already remarked, that most

of the data and facts upon which such a program could be founded did not exist in compiled form at the time the law was enacted. Thus the duty devolved upon the State Department of Health not only to undertake the work of enforcing the law, but also to make a sanitary survey of the state so as to obtain a full knowledge of existing conditions. With inadequate appropriations, the present Commissioner of Health undertook this task and has accomplished excellent results through the activity and support of his corps of sanitary engineers, at the head of which is Mr. Theodore Horton, a native of Massachusetts and a member of this Association.

Time will not permit me to discuss all the aspects of these accomplishments. One of the more important has been the sanitary survey of the important watersheds of the state, including the preparations of maps of the same, showing the chief types and sources of pollution. With the compilation of this data evidence became available for rendering sound decisions as to the degree of sewage purification which should be required of municipalities when the latter submit plans for sewers and sewage disposal for the department's approval according to law.

The grossly polluted public waters in New York state are not utilized to any great extent for potable supplies. In the cases where they are so utilized, filtration systems have been installed for their purification. The most important protection needed for the majority of the potable water supplies is the prevention of the occasional or accidental pollution of a source, ordinarily in good sanitary condition, and the proper control and supervision of the numerous filtration systems.

For the former, the protection afforded by the State Department's rules as already described might well be reinforced by additional provisions of law and by greatly increased appropriations for the additional engineers and inspectors needed to make certain that the violations of the rules are immediately brought to the attention of those responsible for their correction.

The law should be amended in such a manner as to increase the value of the department's rules to the various local boards of water commissioners or water companies without working injustice to the owners of riparian rights upon the watersheds. Above all,

however, the amendments shou'd provide that all plans for new water supplies or for the alteration or enlargement of existing ones, should be submitted to the State Department of Health for approval before their installation could be legally accomplished.

Not only are increased appropriations needed for the work of the engineers, but also for the laboratory study of the existing conditions from the chemical and biological standpoints.

We are painfully aware that except for the scientific investigations carried out for the New York City commissions on additional water supplies and those made by investigators in the employ of some of the larger cities, such as Buffalo, Rochester, and Albany, there has been but little available data of a scientific and technical character systematically arranged which relates to the sanitary quality of the large bodies of surface waters in New York State, and practically nothing regarding the condition of the ground waters except upon Long Island. These latter are, of course, not so important as the former, as they are less subject to pollution.

A systematic study from the laboratory standpoint of all the natural water resources of the state is most desirable; but it cannot be undertaken until very much larger appropriations are made for the state hygienic laboratory.

Only a *slightly increased* appropriation for the laboratory would make it possible to analyze the water from all supplies more frequently; to encourage more efficient water filtration by determining at short intervals the quality of the work done by the filter plants; and to improve the character of the effluents from sewage disposal plants by the assistance it would be to those in charge of such plants to have frequent analyses made of the effluents and of the sewage in successive stages of the processes.

Personally I am of the opinion that not until provision has been made for our efforts in these directions should resources be directed toward the solution of fundamental problems in water and sewage purification and the elimination of trade wastes, by original research. For its successful prosecution, scientific research requires a well-developed foundation of routine accomplishment. By the intelligent and progressive development of the latter field

we bring about conditions favoring the successful excursions into the fields of the unknown.

We in New York would like well to follow the example of Massachusetts and enter the domain of original research but we realize the necessity for the better preparation of our field of effort and for a more accurate knowledge of the problems involved before we make the venture.

DISCUSSION.

THE PRESIDENT. Dr. Pease's paper is now before you.

ROBERT S. WESTON.* I became acquainted with Dr. Pease about ten years ago at a meeting of the American Public Health Association. I have met him at least once a year since, and I want you all to know how large a part of the excellent beginning which the state of New York has made is due to Dr. Pease's personal efforts. I know that he has worked day and night to make this thing a possibility in his own state, and he has done it with very great devotion and at great personal sacrifice.

I think it is very evident from what he has said that the educational part of the preventive work which has to be done against typhoid fever is a very important one. We have reached a place in Massachusetts where further work in the improvement of our water-works systems and sewage disposal plants will have but little effect on the lowering of the typhoid fever death-rate, and where a portion of the money which is now spent for laboratory work and sanitary engineering work might be in the future diverted profitably toward the employment of what might be called typhoid fever missionaries to instruct the local authorities and local physicians in the prevention of typhoid fever by the prevention of throwing away the dejecta of the patients, thus estopping contamination at its source. We have done the more obvious and general work and have reason to feel proud of our State Board of Health for doing it so well. Next must come the more local and more difficult task of the sanitary education of small localities.

PROF. WILLIAM T. SEDGWICK.† Mr. President, as I sat here I have been thinking of one great oversight that seems to me to

* Sanitary Expert, Boston, Mass.

† Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

have occurred when Grover Cleveland died. We heard much then of the various things that he had done, but so far as I know nobody pointed out the fact that he either invented or introduced into common use the phrase "a campaign of education," a phrase which has become the watchword of our modern life, and nowhere more, perhaps, than in this matter of sanitation, so much so that I was glad to hear Dr. Pease say in the earlier part of his paper that it was necessary in all these things to have "a campaign of education."

We were fortunate in Massachusetts when our State Board of Health was reorganized in 1886 that the reorganization was in the hands of a man like our honorary member, Dr. Walcott, who was broad enough to be a good deal more than a physician, and who realized that we had to bring engineering and law to the service of the State Board of Health, ours being a board and not a single-headed commission; and that that board approached these problems *de novo*, and saw that we needed to consider how to go to work to get hold of our water supplies by the right end, and to get at them quickly. If you will turn back to that original act of 1886, which called for the submission to the board of all plans involving changes or improvements in our water supply and sewerage systems, you will realize, I think, as never before, that we were fortunate in having that provision inserted in the statute so that all these matters come under the State Board of Health, i. e., our central state sanitary authority similar to that of the commissioner in New York. That was more than a happy accident; it was a real stroke of genius on the part of the men who, without any particular models except those of Old England, planned for this portion of New England what we think to be the best form of procedure.

We have been greatly favored to-day in hearing about this good work which has been done in the state of New York. It is necessary work and it paves the way for still better work. The hygienic laboratory ought to be strengthened there, the hands of the commissioner ought to be upheld. But I think there is one thing that the state of New York wants quite as much as it does these other matters. It wants a kind of New England Water Works Association which shall bring together the practical managers of

water works, the men behind the guns, from all over the state of New York into a meeting like this, and shall bring Dr. Porter, Dr. Pease, Mr. Horton, and all the others connected with the work into close touch with the practical men. I have known this Association for a good while. Its membership is not limited to Massachusetts; it is not limited even to New England; but I really believe that one of the strongest forces that we have had in New England for the improvement of our water supplies has been this voluntary association of professional craftsmen, water supply men, for the study of these great and important public problems. This association began very early inviting to its membership other prominent water supply men, such as chemists, bacteriologists, and the like. Professor Drown and others now gone used to attend even the early meetings and were always welcome. And that happy conjunction of experts with practical men has gone very far, not only toward the actual improvement of supplies, but toward sound legislative work and toward higher standards, toward that campaign of education which has enabled us in New England to get on as far as we have got.

It is our proud boast that now all over New England the water supplies, broadly speaking, are in good condition. There are exceptions, of course, but, broadly speaking, they are indeed so. And that they are in good condition is very largely due to the coöperation of practical men with scientific men. And as a timely illustration we are hearing from Dr. Pease to-day; we are learning of things that are up to date in a sister state which is a veritable empire in itself. I think we may well congratulate the state of New York that it has got this health administration and that it is carrying on work in this practical direction.

I believe that Dr. Pease is quite right. They must begin at the nearest and most urgent point; they must get things into as good shape as they can immediately before going into elaborate researches; and I do not believe there would be any better way of making the wheels turn rapidly than to form an association like this one, and, until then, to get this one, from time to time, to meet in New York state.

Elbert E. Lochridge.* Mr. President, we have had this word

* Chief Engineer Springfield Water Department, Springfield, Mass.

from New York as to what they are trying to do and what they are doing there, and the statement of the conditions on their watersheds. I would like to bring before the New England members of this Association a point that we have to meet right here at home this fall. We have gotten our watersheds in pretty good shape; we have looked out for their cleanliness; we have gotten adequate storage; we have gotten water supplies which, on account of this storage, in a way take care of themselves with the ordinary care which they can be given. But this fall our water supplies are all drawn low. In Springfield we have but about two months' supply left, and we are beginning to get a little frightened. In several other towns in the western part of the state the reservoirs are very low, and I have no doubt the same thing is true all over New England; I know it is through Connecticut.

With this low stage of the impounded water and the frost which is just about to go into the ground, we are going to have water coming down from melting snows and from heavy rains and filling our reservoirs and giving us for use immediately unstored water; and it seems to me time to call attention very decidedly to the sanitary conditions of our watersheds, as there has been no time in years when the water will go so directly from the watershed, giving the land the wash it needs, and that we do not need for a water supply, as drinking water.

Professor Sedgwick. May I add a word which is suggested by what Mr. Lochridge has said. A young man in my employ in another state called my attention the other day to the fact that the present low state of our water supplies with the general absence of typhoid fever made the old Pettenkofer theory look, as he expressed it, "like thirty cents." That theory was that when we have low ground water, we have high typhoid. Now, we haven't been having high typhoid this autumn of very low ground water, at least in most places we haven't been, and I believe the reason to be just what Mr. Lochridge suggests, namely, that the germs are held back. They have not been allowed to get into the water, or have been unable to get into the water. And he utters a most timely warning when he reminds us that the great epidemics of Plymouth, Penn., and of New Haven, Conn., both occurred under precisely these conditions of heavy rains and melting snows after a

long period of drought, with the washing in of stuff accumulated previously and held back upon the banks.

Prof. Leonard P. Kinnicutt.* I should like to say a few words suggested by what Mr. Lochridge has said. First, however, I wish to express my appreciation of Dr. Pease's account of what the board which he represents has accomplished in the state of New York. I was especially interested in what he said regarding the educational movement, and I believe the holding of sanitary institute meetings all over the state will do more for good sanitation in New York than any other one thing. Such a movement would do a great deal of good in our state where a large majority of the people know nothing and consequently care very little about municipal sanitation. In my own city, for instance, the money necessary to purify satisfactorily the sewage of the city is very, very slow in being appropriated by the city government, because the citizens have absolutely no idea of the necessity of preventing the pollution of inland waters. Once arouse them to this necessity and the common council would quickly find the means for the carrying out of their desires. What better way of arousing interest in municipal sanitation is there than by an educational movement such as Dr. Pease has described?

Regarding the work of the New York State Department of Health, I have seen the results in two or three of the manufacturing towns of northern New York. Ballston Spa, for instance, where all its sewage two years ago ran untreated into Saratoga Lake, now on request or demand of the department has built septic tanks and contact beds for the treatment of sewage.

Take the manufacturing town of Gloversville, with a sewage remarkable for the amount of trade waste it contains; they have been compelled to take action and are now conducting, under the supervision of Harrison B. Eddy, one of our members, a most interesting series of experiments so as to be able to treat the sewage in a satisfactory manner. The same can be said for towns and cities all through the state, and is the visible result of the work that Dr. Pease has so well described to us to-day.

This is a long introduction to what I really rose to speak about, and which was suggested to me when Mr. Lochridge said that as a

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

rule the water supplies of Massachusetts are in a state that they can take care of themselves. To that statement I cannot agree. Our water supplies are not in a state where they can take care of themselves. They need and require constant attention and supervision. Take, for instance, the water supply of Worcester, which, like many Massachusetts towns, is an impounded reservoir supply, and may be considered as an excellent supply. The watershed contains no small villages and is sparsely inhabited, yet it is not a water supply that can take care of itself, nor a supply without sources of danger, sources that may at any time give rise to a typhoid fever epidemic. What are these sources? On the watershed of one of the impounded reservoirs there are ten sources where it is possible for animal matter, namely, the refuse from man or man's habitations, to pollute the water. On the watershed of the other reservoir the sources of pollution are not so many, but the reservoir is situated within two miles from the end of one of the most popular trolley lines, and on Sundays and holidays many persons can be seen wandering along the shores of the reservoir. What is true of Worcester is true of many impounded reservoirs in our state, and such water supplies cannot take care of themselves, but need constant supervision and inspection. Every watershed of a potable water should have special guards, appointed by the water board or board of health, whose sole duty should be the guarding of the watershed from pollution.

Professor Sedgwick and Mr. Lochridge have pointed out the danger of pollution of impounded waters at the present time due to the fact that the water in all our reservoirs is low, and that the first real storm will not only bring into the reservoir all the dirt that has accumulated during the past dry summer and autumn, but, owing to the small amount of water in the reservoirs, there will be little time for sedimentation, and the water from the watershed will quickly be carried into the supply pipes. The warning that they have given of the necessity of immediately inspecting the watersheds and removing all sources of pollution is most timely, and if not heeded will be sure to result in a high typhoid fever death-rate during the present winter or coming spring.

The effect of a slight rainfall such as we had in Worcester two weeks ago was shown by the immediate increase of about fifty

per cent. in the number of bacteria in a given quantity of one of our reservoir waters.

Dr. Pease. Mr. President and Members of the Association: I wish to thank you for the very kind expressions which have been voiced this afternoon, and I am particularly gratified at the manner in which you have taken the matter of the educational work which we are trying to carry on in New York state. Just as an example of the fact that people really are interested in these hygienic problems, I would like to relate an instance where we showed this hygienic exhibition which I spoke of — models of sand filtration systems and mechanical filtration systems and of septic tanks. We demonstrated this in conjunction with our large traveling tuberculosis exhibition in the city of Albany, and we had to get our demonstrators to keep the people away from the hygienic exhibitions in order to interest them in the tuberculosis exhibit.

Our people are tremendously interested in all these lines of technical work conducted by boards of health and particularly by water departments, and the only reason they do not take even more interest and know more about them is because the water departments do not organize little excursions out to the filtration systems to demonstrate to the people what they are actually doing. The Health Department of the state of New York would have gone on with meager appropriations until the crack of doom if they had not interested the people of the state in what they were doing. The old method had been tried for nearly an entire generation, and it was almost impossible to get additional money out of the legislature. Now we are going to get it because the people are interested in our work and will see to it that proper appropriations are made.

R. C. P. Coggeshall.* Mr. President, as I am personally largely responsible for the invitation which brought Dr. Pease here, I want to say that I feel more than repaid by what has been said by him and by the discussion that has taken place, and I sincerely hope that we will have the pleasure of hearing him again.

* Superintendent Water Works, New Bedford, Mass.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 9, 1908.

President Martin in the chair (Vice-President King presiding later).

The following members and guests were in attendance:

Honorary Member.

F. W. Shepperd. — 1.

Members.

C. H. Baldwin, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, J. E. Beals, F. D. Berry, A. E. Blackmer, J. W. Blackmer, George Bowers, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, C. E. Chandler, J. C. Chase, Harry W. Clark, R. C. P. Coggeshall, M. F. Collins, G. W. Cutting, Jr., F. W. Dean, John Doyle, M. J. Doyle, E. D. Eldridge, J. A. Fitch, F. F. Forbes, E. V. French, F. L. Fuller, C. W. Gilbert, D. H. Gilderson, Albert S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., D. A. Heffernan, J. L. Howard, C. L. Howes, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, J. J. Kirkpatrick, Hugh McLean, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, F. L. Northrop, E. M. Peck, T. A. Peirce, A. M. Quick, Henry Roberts, L. C. Robinson, Ransom Rowe, H. W. Sanderson, A. L. Sawyer, W. H. Sears, E. M. Shedd, C. W. Sherman, W. E. Smith, G. A. Stacy, J. T. Stevens, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, G. W. Travis, L. L. Tribus, W. H. Vaughn, C. K. Walker, J. H. Walsh, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow. — 84.

Associates.

The Anderson Coupling Company, by Charles E. Pratt; Ashton Valve Company, by C. W. Houghton; Builders' Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edward F. Hughes; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Sons Company, by Charles F. Glavin; H. Mueller Manufacturing Company,

by George A. Caldwell; National Meter Company, by C. H. Baldwin, H. L. Weston, and J. G. Lufkin; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Union Water Meter Company, by Edward P. King; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. H. VanWinkle. — 21.

Guests.

R. Lorine, M.D., Coronado Beach, Cal.; J. G. Hill, water commissioner, Lowell, Mass.; John H. Damon, Plymouth, Mass.; A. Fleming, water commissioner, Lawrence, Mass.; and E. L. Field, Northfield, Vt. — 5.

On motion of Mr. Bancroft the Secretary was directed to cast the ballot of the Association in favor of the election of the following named as active members, and he having done so, they were declared duly elected: O. C. Merrill, Berkeley, Cal., assistant engineer reporting on the practicability and cost of a private water supply for the buildings and campus of the University of California at Berkeley; Dr. John C. Otis, Poughkeepsie, N. Y., commissioner of public works and president of the Board of Public Works.

The first paper on the program for the afternoon was by Mr. Leonard Metcalf, consulting engineer, Boston, Mass., on "Wrought-Iron Cement-Lined Water Pipe." Before presenting his paper Mr. Metcalf said:

"I would like to take this opportunity of saying a word to you in regard to the work of your Committee on Water and Water Power Diversion Awards. You will recollect that we sent out postal-card inquiries to the membership some time ago asking for replies from all who had information in regard to damages which had been awarded, or awards which had been made under order of the court or other judicial authority in water-power diversion cases, and we have received a certain number of replies. It seemed to us, however, that we ought to have more than we have thus far received, and we are, therefore, sending out a second set of postal cards, asking you if you will not please return them, stating definitely whether you have or have not any information which you can give us on this point. We don't want to let any good information escape the Association if we can help it. We are also sending out to those who have signified the fact that they

have such information circulars upon which the essential data for which we are asking can be given, and we will be very glad to send them to any others whom you may suggest to us as probably having information, if we haven't them upon our list."

Mr. Metcalf then proceeded to give a synopsis of his paper, which was before the members in proof print. The following-named gentlemen took part in the discussion: Arthur E. Blackmer, Robert S. Weston, E. W. Kent, R. C. P. Coggeshall, Frank L. Fuller, Frank A. Barbour, Leonard C. Robinson, President Martin, John C. Chase, Joseph A. Fitch, J. C. Hammond, Jr., Edward V. French, and Edwin C. Brooks.

The next paper was entitled "Newton (N. J.) Water Works, with Special Relationship to the Storage and Diversion Features and Legal Proceedings Growing Therefrom," by Louis L. Tribus, consulting engineer, New York. The subject was discussed by Richard A. Hale, Charles E. Chandler, William S. Johnson, George A. King, and Leonard Metcalf.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 13, 1909.

The President, Mr. Alfred E. Martin, in the chair.

The following-named members and guests were present:

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, G. A. P. Bucknam, James Burnie, W. L. Butcher, L. G. Carleton, George Cassell, J. H. Child, C. E. Childs, F. L. Clapp, H. W. Clark, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, G. W. Cutting, Jr., L. E. Daboll, C. E. Davis, M. J. Doyle, E. R. Dyer, E. D. Eldridge, C. R. Felton, F. F. Forbes, F. L. Fuller, F. J. Gifford, C. W. Gilbert, J. C. Gilbert, Albert S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, D. A. Heffernan, H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, J. J. Kirkpatrick, H. O. Lacount, E. E. Lochridge, A. R. McCallum, Hugh McLean, N. A. McMillen,

D. E. Makepeace, A. E. Martin, F. E. Merrill, G. F. Merrill, H. A. Miller, William Naylor, F. L. Northrop, E. M. Peck, Henry Roberts, H. E. Royce, P. R. Sanders, E. M. Shedd, C. W. Sherman, G. A. Stacy, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. K. Walker, J. C. Whitney, George E. Winslow. — 78.

Associates.

Allen & Reed, Inc., by Murray G. Millikin; Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by F. M. Bates; Builders' Iron Foundry Company, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edw. F. Hughes; George E. Gilchrist Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, H. D. Winton, and Walter A. Hersey; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Sons Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by H. G. Lufkin and H. L. Weston; New York Continental Jewell Filtration Company, by R. E. Milligan; Norwood Engineering Company, by H. W. Hosford; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Neptune Meter Company, by H. H. Kinsey; Union Water Meter Company, by Edw. P. King. — 21.

Guests.

Millard F. Hicks, treasurer Portland Water District, and Chesley L. Ward, superintendent Meter Department, Portland, Me.; Dwight L. Agnew, North Scituate, Mass.; Ivers M. Low, superintendent, Weymouth, Mass.; F. H. Hayes, of the F. H. Hayes Machinery Company, Boston, Mass.; F. J. Merrill, W. Hoare, and E. C. Allen, engineer, Manchester, Mass.; George Goodhue, Concord, N. H.; C. E. Hall, Wallingford, Conn.; C. H. Tuttle, Bristol, R. I. — 11.

Mr. Bertram Brewer, city engineer of Waltham, Mass., gave an interesting talk, illustrated by lantern slides, on "Cuba and the Havana Water Works."

The following-named were elected to membership, their applications having been duly approved, and one ballot cast for them by the Secretary, in accordance with the vote of the Association on motion of Mr. Frank L. Fuller:

Active. — Herbert D. Pease, Albany, N. Y., director of the New York Hygienic Laboratory; Leonard M. Wachter, Albany, N. Y., chemist at Albany Filtration Plant and sanitary chemist, New York State Department of Health; Arthur E. O'Neil, Watertown,

Mass., superintendent of pumping stations, Metropolitan Water Works; Millard F. Hicks, Portland, Me., treasurer Portland Water District; Charles H. Tuttle, Bristol, R. I., superintendent Bristol and Warren Water Works; Fred M. Hutchinson, Somerville, Mass., engineer and foreman with Somerville Water Works.

Associate. — N. H. Hayes, Hayes Machinery Company, South Boston, Mass.

Mr. Alfred E. Martin, the retiring President, then delivered the following address:

Address of the Retiring President.

Gentlemen of the New England Water Works Association, — Among the many memories which have kept pace with my journeyings from boyhood days is one of a remark attributed to a certain boy in answer to another's attempt to air his self-supposed superior knowledge of a certain dead language by quoting the old, familiar phrase, "*Tempus fugit.*" "Oh, yes," said the former, "I know that, and my father says it *fugits* like everything." It seems to me as I stand here to-day that the above applies very forcibly to the year just closed, for no twelve months of my existence have ever gone into history with such remarkable celerity. I can hardly realize that it is fully a year since my advent as your president, and I almost feel like singing with the poet,

> "Backward, turn backward, O Time, in thy flight."

But time never turns backward, and be our journey long or short, few of us, I think, would care to try it over or make a wiser use of our opportunities.

But Father Time has a sadder story for us to-day, for the "grim reaper" has been busy in our ranks and has taken eight of our active and one of our honorary members on the journey to that country from whose bourn no traveler returns. I will merely call their names here, for their history has already been inscribed on our records, and to those of you who knew them intimately there is no necessity for eulogy such as my ungifted tongue could pronounce. I will ask the members to stand while I read the list of those who have crossed the great divide during the last year:

R. C. Bacot, Jr., superintendent meter department, Port Chester, N. Y. Elected to membership in this association December 12, 1888. Died December 12, 1908.

Charles H. Campbell, 126 Liberty Street, New York City. Elected to membership June 28, 1905. Died March 24, 1908.

Bartholomew Dwyer, assistant superintendent water works, Hartford, Conn. Elected to membership September 13, 1905. Died December 14, 1907.

I. T. Farnham, city engineer, Newton, Mass. Elected to membership December 13, 1905. Died September 19, 1908.

A. W. Hunking, Lowell, Mass. Elected to membership June 11, 1890. Died November 12, 1908.

J. O. A. Laforest, Quebec, Canada. Elected to membership December 14, 1892. Died December 28, 1907.

Claude P. Nibecker, sanitary engineer, Pittsburg, Pa. Elected to membership November 19, 1905. Died November 10, 1908.

George E. Wilde, assistant superintendent Distribution Department, Metropolitan Water Works, Boston, Mass. Elected to membership June 18, 1886. Died July 17, 1908.

Charles Hermany, chief engineer and superintendent of the Louisville, Ky., Water Company. Elected honorary member of this Association September 14, 1904. Died January 18, 1908.

All of the above, except the last named, were active members of this Association, and he was an honorary member.

Our total membership is now 696, a net loss for the year of 6. At first thought this would appear a retrogression, but when we note that the above is the absolute *net membership*, that all whose assessments were overdue have been dropped from the rolls, it is not in reality so bad as it seems, for we have 696 actual paying members,— no dead wood at all.

Right here it may not be out of place to suggest that if some way could be devised to keep the Secretary more closely in touch with those members who are liable to get in arrears, it might be possible to avoid such a large list of delinquents as has appeared this year, namely, thirty-eight, of whom seventeen have been reinstated upon payment of all arrearages. It would seem a good plan for the Executive Committee to take this matter up and recommend an amendment to the By-Laws to the effect that the

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year. Members.	Associate.	Honorary.	Total.	Annual Convention. Place.	Date.	Receipts.	Expenditures.	Cash Balance.
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	702	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10

* Deceased. † Not including December Journal and reprints. ‡ Does not include $1 815 invested in bonds.

Secretary shall remind those who are getting behind in their dues at least quarterly, and it seems to me that by thus oftener calling their attention to the fact, fewer would let their membership lapse by neglect or forgetfulness. I can hardly believe that twenty-one members would have allowed themselves to be dropped from this Association if they could have been reminded of their liability earlier in the game, so to speak.

Our finances are still in a prosperous condition, the Treasurer's report showing upward of $2 700 cash on hand, besides an investment of $1 815 for railroad bonds, the par value of which is $2 000, and which would now sell in the market for $1 920, thus making available assets of over $4 600, an increase of $600 or more over last year.

Our JOURNAL has kept pace with the growth of this Association, and is, as it has always been, an up-to-date publication. It was with much regret that I learned as long ago as our June meeting that Mr. Sherman would not be a candidate for reëlection as its editor. For ten years he has had charge of its publication, and under his care it has grown to be of the greatest value to the members of the Association. He has given to it fully and unreservedly of his time and strength, and it is not surprising that with the increased responsibilities of his regular occupation he has come to feel that it is too much of a burden to be longer borne. Without doubt much of its value and worth to-day are due to his ceaseless and untiring devotion to and love for the Association, whose proceedings it chronicles. If we must lose him we are to be congratulated that in his successor we are to have one who will undoubtedly follow in his footsteps and be guided and advised, for a time at least, by his experienced mind and wise counsels. His table showing the progress of the Association from its beginning is again published as a part of this report, and includes the year 1908.

Our winter meetings have proven helpful and interesting and have all been well attended, and I think that none who have been present at them have ever gone away with the feeling that they have not been well repaid for the effort, if in no other way than in the sociability and good-fellowship thus engendered between the members.

On the 21st of June the Association visited Plymouth, and under the efficient management of Messrs. King, of Taunton, and Tower, of Cohasset, the committee appointed to arrange for the excursion, also in spite of the weather, which was extremely hot and unfavorable, about eighty members and guests passed a very enjoyable day. After a short meeting at the armory, where we were welcomed and very hospitably entertained by the town officials, the workshop of the water department was inspected and the process of manufacturing large-size wrought-iron, cement-lined water pipe was witnessed and proved interesting to us all. Pilgrim Hall, the Rock, and the monument were the next objects of interest, and then electric cars were boarded for a ride to Hotel Pilgrim, where an excellent shore dinner was served. An interesting incident of the day was the meeting of the surviving charter members of this Association, six in number, namely, H. G. Holden, R. W. Bagnell, C. K. Walker, F. E. Hall, A. S. Glover, and R. C. P. Coggeshall, and as a result of the meeting a group photograph of them now adorns a page of the September number of the JOURNAL. Of the six, four are ex-presidents of the Association, the fifth has been our secretary and junior editor of the JOURNAL, and the sixth, Mr. Bagnell, has been made a life member of this Association. After the dinner an opportunity was given to witness the work of laying the before-mentioned cement-lined pipe. The speaker was forced to miss this part of the program by a long search for head covering, caused by a too careful waiter who could not remember the place where he put it. I have no doubt the process was interesting and instructive to those who saw it.

The annual convention of the Association, in accordance with the expressed wish of many of its members, was held in Atlantic City, N. J., September 23, 24, and 25. The attendance was not so large as could have been desired or expected, but those who were present were well repaid. The headquarters of the Association were at the Traymore Hotel. Upwards of two hundred and fifty members and guests were registered, nearly all of whom made the Traymore their home for the three days. The business meetings were well attended and very helpful, and many able papers, followed by general discussion, were presented. I wish to express my personal obligation to the general chairman, Allen Hazen, for

his zeal in marshaling members to the convention hall where the business sessions were held.

While business was the chief object of the assemblage, yet there was time for recreation as well. The roller chair parade on the board walk, in which over ninety double chairs were in line, was a novel and pleasing experience. The reception to the officers and their wives which followed was enjoyable and promoted sociability. The exhibition drill of the life-saving crew, which was ordered by the mayor of the city as a compliment to the Association, proved an interesting and instructive feature. On Friday, the last day, a trolley trip was indulged in to the pumping station of the Atlantic City Water Works. Some time was profitably spent looking over the plant, and here the speaker (at least) had his first introduction to that active resident of the state of which so much has been written and spoken, namely, the "Jersey mosquito."

Among the various committees which have been appointed during the year are the following:

At the March meeting a committee of five was appointed to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country.

At the September convention a committee of seven was appointed to gather statistics relative to the depth at which water pipes are laid and the resultant experiences with frozen pipes in New England and different places of the country.

When these committees shall have formulated and presented their final reports they should make a most valuable addition to our literature.

Reports of the Secretary, Treasurer, Editor, and Auditing Committee will show in detail the standing of the Association, financially and otherwise. The faithful work of these officers should not pass unnoticed, and the Association will do well to continue them in office.

My duties of the past year have been lightened by the active and earnest work on the part of the various committees, to whom I return heartfelt thanks.

From the inception of this organization, all through the inter-

vening years to the present time, the work has been characterized by devotedness of purpose which must result in new life ever being diffused throughout the ranks, and in the maintenance of that high standing in the community to which the Association is entitled.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of Secretary.

Mr. President and Members of the New England Water Works Association, — Your Secretary submits the following report of membership, moneys received, and disbursements approved on account of the New England Water Works Association for the year ending December 31, 1908:

MEMBERSHIP.

The present membership of the Association is 696; that of one year ago was 702, a loss of 6 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows:

MEMBERS.

January 1, 1908.	Total number		636	
	Withdrawals:			
	Resigned	15		
	Died	8		
	Dropped	38	61	575
		—	—	
	Initiations:			
	January	4		
	February	4		
	March	5		
	June	10		
	September	8		
	November	1		
	December	2		
		—	34	
	Members elected in 1907, qualified in 1908		2	
			—	36

	Reinstated:				
	Members dropped in 1907		5		
	Members dropped in 1908		17		22

HONORARY MEMBERS.

January 1, 1908.	Honorary members		15		
	Died		1		14

ASSOCIATES.

January 1, 1908.	Total number of associates		51		
	Withdrawals:				
	Dropped	1			
	Resigned	3	4	47	
	Initiations:				
	February	1			
	September	1		2	49
January 1, 1909.	Total membership				696

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1908.

RECEIPTS.

Initiation fees			$170.00
Annual dues:			
Members	$1 920.00		
Associates	750.00	$2 670.00	
Fractional dues:			
Members	$12.00		
Associates	5.00	17.00	
Past dues		20.62	2 707.62
Advertisements			2 118.75
Subscriptions			178.50
Journals sold			264.85
Sundries			86.70
Total receipts			$5 526.42

DISBURSEMENTS.

Journal	$2 219.15
June excursion	19.80
Assistant Secretary	600.00
Stationery and printing	612.89
Rent	400.00
Advertising Agent	264.40
Editor	300.00
Secretary	200.00
Stenographer	206.00
Incidental expenses	155.65
Membership list	171.00
Reprints	279.50
Music	75.00
Stereopticon	57.50
Treasurer	50.00
Badges	72.00
Insurance	15.00
Library	6.00
Total disbursements	$5 703.89
Expenditures in excess of receipts	$177.47

At present there is due the Association:

For advertisements	$498.75
For reprints	19.80
For initiation fees and dues	11.00
For Journal	1.00
For Standard Specifications	1.20
	$531.75

I know of no outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.

1908.				
Jan.	6	Balance on hand		$4 480.30
Aug.	1	Dividend, Peoples' Savings, Worcester,		64.64
Nov.	1	Coupons, L. S. & Mich. So. R. R. bonds		80.00
Dec.	9	Dividend, Mechanics Savings Bank, Reading		35.30
Feb.	7	Rec'd of Willard Kent, Sec'y,	$1 387.90	
March	9	,, ,, ,, ,, ,,	664.70	
April	6	,, ,, ,, ,, ,,	493.10	
May	4	,, ,, ,, ,, ,,	574.95	
June	6	,, ,, ,, ,, ,,	251.05	
July	10	,, ,, ,, ,, ,,	273.95	
Sept.	4	,, ,, ,, ,, ,,	516.87	
Nov.	10	,, ,, ,, ,, ,,	277.15	
Dec.	9	,, ,, ,, ,, ,,	599.05	
1909.				
Jan.	5	,, ,, ,, ,, ,,	487.70	5 526.42
				$10 186.66

EXPENDITURES.

Paid bills, as per itemized statement		$7 475.56
BALANCE ON HAND.		
Deposit, Peoples' Savings Bank	$1 664.64	
,, Mechanics Savings Bank	1,000.00	
,, First National Bank, Reading	17.59	
Deposit, Liberty Trust Co., Boston	28.87	2 711.10
		$10 186.66

ASSETS AND LIABILITIES.

ASSETS.

Cash balance on hand	$2 711.10
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R., 4%, due May 1, 1931. Book value, $1,815.00. Market value	1 920.00
	$4 631.10

LIABILITIES.

Bill due Advertising Agent	$62.00
Net assets	4 569.10
	$4 631.10

READING, MASS., January 5, 1909.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1908.		
January 21	Blodget, Merritt & Co., Lake Shore & Mich. So. R. R. bond	$1 815.00
	Accrued interest	18.67
February 7	Samuel Usher, December, '07, JOURNAL and reprints,	594.68
	D. Gillies' Sons, printing	18.00
	W. N. Hughes, printing	43.75
	The Brunswick, music, January meeting	15.00
	L. M. Bancroft & Son, bond	15.00
	American Society of Civil Engineers, binding	6.00
	Hub Engraving Company, plates	4.33
	Miss J. M. Ham, salary for January	50.00
8	D. Gillies' Sons, stationery	52.84
	W. N. Hughes, envelopes and printing	70.00
March 2	The Brunswick, music, February meeting	15.00
	Thomas P. Taylor, stereopticon	10.00
	Hub Engraving Company, plates	8.98
	Miss J. M. Ham, salary for February	50.00
9	W. N. Hughes, printing	1.85
	D. Gillies' Sons, printing	4.00
	William E. Whittaker, work on plans	5.00
	Boston Society of Civil Engineers, rent to February 29, 1908	100.00
30	Hub Engraving Company, plates	9.40
	Samuel Usher, advance copies	15.00
	The Brunswick, March meeting, music	15.00
	Bacon & Burpee, report of January, February, and March meetings	59.00
	Miss J. M. Ham, salary for March	50.00
	Thomas P. Taylor, stereopticon	10.00
	Charles W. Sherman, salary to March 31	75.00
	Charles W. Sherman, copyright, postage, etc.	9.50
April 7	Willard Kent, salary as Secretary to March 31	50.00
	Willard Kent, expenses	60.50
15	Robert J. Thomas, advertising agent, to April 30	69.65
20	Hub Engraving Company, plates	31.99
	Samuel Usher, March JOURNAL and reprints	267.58
	Miss J. M. Ham, salary for April	50.00
	Miss J. M. Ham, sundry expenses	34.65
May 4	W. N. Hughes, envelopes and printing	45.00
	Hub Engraving Company, plates	38.22
	Samuel Usher, printing Constitution and List of Members	171.00
	Amount carried forward	$3 959.59

	Amount brought forward	$3 959.59
May 19	Hub Engraving Company, plates	14.05
	William E. Whittaker, tracings	10.00
	John Wiley & Sons, electro plates	1.25
25	Miss J. M. Ham, salary for May	50.00
June 6	Hub Engraving Company, plates	11.08
	Boston Society of Civil Engineers rent to May 31, 1908	100.00
26	H. D. Atwell, cut of Plymouth and tickets	3.55
	Miss J. M. Ham, salary for June	50.00
July 6	D. Gillies' Sons, printing circulars	11.25
	Willard Kent, salary to July 1	50.00
	Willard Kent, expenses	10.00
	Charles W. Sherman, salary to June 30	75.00
	Charles W. Sherman, expenses	4.75
10	Samuel Usher, June JOURNAL	538.16
23	Samuel Usher, Standard Specifications	27.25
	W. N. Hughes, stamped envelopes and printing	24.00
	Robert J. Thomas, advertising agent, to July 8	69.75
28	Lewis M. Bancroft, deficit, Plymouth Excursion Committee	19.80
	Samuel Usher, reprints	53.00
August 28	Suffolk Engraving Company, plate	3.78
	H. W. Spooner, typewriting	3.00
	Miss J. M. Ham, salary for July	50.00
September 2	Hub Engraving Company, plates	1.70
	Miss J. M. Ham, salary for August	50.00
16	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage, express, etc.	6.00
21	Boston Society of Civil Engineers, rent to August 31,	100.00
	Hub Engraving Company, plates	5.24
October 6	W. N. Hughes, postal cards and circulars	10.75
	Samuel Usher, advance copies	7.50
	Whitehead & Hoag Company, badges	72.00
	Miss J. M. Ham, salary for September	50.00
9	Alfred Moore, stereopticon, Atlantic City	17.50
	Traymore Hotel Company, labor, etc.	7.40
	Hub Engraving Company, plates	2.00
	D. Gillies' Sons, printing circulars	14.75
14	W. N. Hughes, letter heads	4.00
	Bacon & Burpee, report of twenty-seventh annual convention	94.25
	Willard Kent, salary to October 1	50.00
	Willard Kent, expenses	21.00
	Amount carried forward	$5 728.35

	Amount brought forward	$5,728 35
October 14	Hub Engraving Company, plates	2.00
26	Miss J. M. Ham, salary for October	50.00
	Miss J. M. Ham, expenses	82.87
November 24	Thomas P. Taylor, stereopticon	10.00
	The Brunswick, music at November meeting	15.00
	D. Gillies' Sons, printing circulars	4.50
	William E. Whittaker, preparing drawing	1.00
	W. N. Hughes, printing circulars	7.00
	Hub Engraving Company, plates	1.00
27	Hub Engraving Company, plates	17.72
	Miss J. M. Ham, salary for November	50.00
	Robert J. Thomas, advertising agent, to November 30	63.00
December 11	Hub Engraving Company, plates	24.64
	Boston Society of Civil Engineers, rent to November 30, 1908	100.00
	Samuel Usher, September JOURNAL and reprints	355.66
18	Hub Engraving Company, plates	10.80
	The Brunswick, music, December meeting	15.00
	Charles W. Sherman, salary to December 31, 1908,	75.00
	Charles W. Sherman, postage and expenses	6.50
	Thomas P. Taylor, stereopticon	10.00
	Willard Kent, salary to December 31	50.00
	Willard Kent, expenses	43.40
21	W. N. Hughes, dues book and circulars	28.00
	Lewis M. Bancroft, treasurer, salary to December 31, 1908	50.00
25	Miss J. M. Ham, salary for December	50.00
	Miss J. M. Ham, expenses, telephone and postage	32.25
28	Samuel Usher, printing advance copies	27.25
	Bacon & Burpee, reporting November and December meetings	52.75
1909.		
January 6	D. Gillies' Sons, printing	28.50
	W. N. Hughes, printing, Committee on Depth of Laying Water Pipes	49.75
	Samuel Usher, December JOURNAL and reprints	433.62
		$7 475.56

The Editor, Mr. Charles W. Sherman, submitted the following report:

Report of the Editor.

Boston, January 13, 1909.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1908.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1908, and which are consequently not included in the Secretary's and Treasurer's statements); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat larger in total pages, and contains the same number of pages of text, as that of the preceding year; and is larger than any preceding annual volume, with one exception.

Illustrations. — The total cost of illustrations for the year, including printing, has been $355.36, or 13.0 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Advance copies of three of the papers presented during the year have also been printed, one of which has not yet appeared in the Journal. The net cost to the Association for reprints and advance copies has been $203.70 (assuming that the December reprints chargeable to members are promptly paid for).

Circulation. — The present circulation of the Journal is:

Members, all grades	696
Subscribers	60
Exchanges	24
Total	780

a decrease of 5 over the preceding year.

Advertisements. — The December issue contained $25\frac{1}{2}$ pages of paid advertising, which, if maintained throughout the year, would mean an annual income from this source of $1 760. A year ago the figures were $28\frac{1}{4}$ pages and $1 940, showing considerable decrease during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $49.00 have been sold. Five hundred copies have been printed, at a cost of $27.25, representing a net gain of $21.75 for the year. The net gain up to a year ago had been $139.75, so that the total net gain from this source to date is $161.50. There are still about two hundred and eighty copies of specifications on hand, or about $28.00 worth if sold at retail.

The Association has a credit of $1.69 at the Boston Post-office, being the balance of the money deposited for payment of postage upon the Journal at pound rates. I know of no outstanding bills against the Association on account of the Journal.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

Statement of Material in Volume XXII, Journal of the New England Water Works Association, 1908.

Number.	Date.	Pages of								
		Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	58	28	86	–	32	4	4	126	2
2	June	164	10	174	–	30	4	18	226	28
3	September	93	27	120	–	28	4	7	159	5
4	December	110	10	120	8	28	4	10	170	12
	Total	425	75	500	8	118	16	39	681	47

TABLE No. 2.

Receipts and Expenditures on Account of Volume XXII, Journal of the New England Water Works Association, 1908.

Receipts.		Expenditures.	
From advertisements . .	$2 118.75	For printing Journal . .	$1 490.75
From sale of Journals . .	264.85	For preparing illustrations,	207.36
From sale of reprints . . .	28.50	For editor's salary	300.00
From sale of cuts	11.70	For editor's incidentals .	28.60
Subscriptions	178.75	For advertising agent's commissions	264.40
	$2 602.55	For reporting	206.00
Net cost of Journal . . .	131.06	For reprints and advance copies	236 50
	$2 733.61	Gross cost of Journal . .	$2 733.61

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV TO XXII, INCLUSIVE, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	VOL. XIV. 1899–1900.	4 Numbers of VOL. XV. 1900–1901.	VOL. XVI. 1902.	VOL. XVII. 1903.	VOL. XVIII. 1904.	VOL. XIX. 1905.	VOL. XX. 1906.	VOL. XXI. 1907.	VOL. XXII. 1908.
Average edition (copies printed)	1 100	1 200	1 200	1 200	900	900	900	1 085	1 000
Average membership	583	586	571	587	596	625	665	693	699
Circulation at end of year	640*	617*	648*	656*	667	705	767	785	780
Pages of text	345	363	403	430	491	587	495	500	500
Pages of text per 1 000 members	600	618	707	733	824	939	745	722	715
Total pages, all kinds	485	536	584	619	794	784	662	669	681
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254	995	964	976
GROSS COST:									
Total	$1 954.15	$2 104.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88	3.95	4.01
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87	3.82	3.91
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67	5.85	5.70	5.88
Per member per 1 000 pp. text	9.71	10.13	10.60	10.72	10.00	8.91	7.81	7.62	8.02
NET COST:									
Total	$347.55	$332.90	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15	$131.06
Per page	.72	.62	1.07	1.25	.82	1.37	.58	.72	.19
Per member	.60	.57	1.09	1.31	1.09	1.72	.58	.70	.19
Per member per 1 000 pages,	1.23	1.06	1.87	2.12	1.30	2.20	.88	1.04	.28
Per member per 1 000 pp. text	1.73	1.57	2.71	3.05	2.22	2.93	1.18	1.39	.39

* Exclusive of three hundred sample copies.

Mr. George Cassell, chairman of Finance Committee, submitted the following report:

Report of Finance Committee.

Boston, Mass., January 11, 1909.

We have examined the books and accounts of the Secretary and Treasurer of the New England Water Works Association and find them correct, the several amounts collected by the Secretary having been turned over to the Treasurer and his various disbursements being supported by proper receipts duly approved.

The accounts and books are properly kept and the very satisfactory manner in which this department of the Association is conducted is largely due to the exceedingly efficient service of the Assistant Secretary.

We recommend that the books be closed on the first day of January and remain closed until the annual meeting, in order that the Treasurer and Finance Committee have ample time to attend to their duties.

Respectfully submitted,

GEORGE CASSELL,
JOHN C. CHASE,
WILLIAM E. MAYBURY,
Finance Committee.

Mr. Cassell. I might add, Mr. President, that the recommendation, as made by your Finance Committee, is in order to provide so that the bills approved by the Secretary will get into the hands of the Treasurer before the Treasurer closes his books, thereby avoiding the discrepancy in the two accounts as printed in the Journal, which necessitates a footnote of explanation. The Finance Committee think it would be much better and more satisfactory, and remove any doubt upon anybody's part after reading the Journal, if the suggestion we make is adopted.

On motion of Mr. George A. Stacy the reports of the Secretary, Treasurer, and Editor were accepted and ordered placed on file and spread on the records of the Association.

On motion of Mr. Coggeshall, the report of the Finance Committee was accepted and its recommendation adopted.

Reports of Committees.

STANDARD SPECIFICATIONS FOR FIRE HYDRANTS.

Mr. H. O. Lacount, chairman of the Committee to Prepare a Standard Specification for Fire Hydrants, presented the following report:

Mr. President and Gentlemen of the New England Water Works Association,— The retiring President in his address gave a list of the committees appointed last year, and as he did not mention the Committee on Hydrants, I presume it is to be inferred that it was appointed more than a year ago. As chairman of the committee, I am forced to agree with the father of the lad mentioned in the retiring President's address that "*tempus fugits* like everything." I will not apologize for Father Time, because he cannot help it, and I feel rather embarrassed in attempting to apologize for the committee for not having made a report to you before. I regret that we have not, and that we are not ready yet to bring out a complete set of specifications. We can, however, report some progress.

The committee has had two meetings, at each of which we spent practically an entire afternoon on the work. We have been in communcation with practically all of the manufacturers of hydrants of whom we have knowledge, have had the benefit of their suggestions, and the matter is gradually taking form. We hope that before the administration on which we begin to-day ends we shall have the subject threshed out to a finish. That you may have some idea along what lines the committee is working, I have here what may be called a skeleton of specifications, which I will read.

Skeleton of Specifications.

1. Size.
   - *a.* Size of hydrants must be designated by the valve opening, at least 5-inch for two hose connections, 6-inch for three or four connections.
   - *b.* Area of waterway at smallest part when hydrant is wide open must not be less than that of the valve opening.
2. General Design.
   - *a.* Any changes in diameter of water passage through the barrel shall have easy curves, all outlets to have well-rounded corners of good radius.
   - *b.* Design such that with ordinary usage hydrants will not cause excessive water hammer.
3. Hose Nipples and Valves.
   - *a.* Nipples of bronze, threaded with fine thread and pinned. "Leading" not permitted.
   - *b.* Hose threads to be same as existing in city where hydrant is to be used; otherwise and where practicable, same as N. F. P. A. Standard, 1906.
   - *c.* Hose valves of bronze or of iron with bronze trimmings, — brief specifications.
4. Hydrant Gate and Seat.
   - *a.* Material.
   - *b.* With gate type of valve sufficient clearance to offset corrosion.
5. Drip Valve.
   - *a.* Positively operating and non-corrodible, to completely drain barrel.
   - *b.* Seat to be securely fastened in barrel; all other parts to be removed through hydrant top.
6. Operating Stem.
   - *a.* Material and size.
   - *b.* Stem nut.
   - *c.* Style of thread, Acme standard.

7. Stuffing Box and Gland.
   a. Material.
   b. Material and size of gland bolts.
8. Hydrant Top.
   a. Weatherproof and provision for oiling.
9. Markings.
10. Hose Caps for all outlets.
11. Test.
    Shop test of 250 or 300 pounds, or twice working pressure.
12. Direction of Opening to the left.

The President. If there is nothing to be said on this report, it will be received as a report of progress and the committee continued. The next business is the report of the committee appointed to collect data relating to awards that have been made for damages resulting from the diversion of water. Mr. Charles T. Main, chairman of the committee, has sent the following communication, which the Secretary will read:

WATER AND WATER POWER DIVERSION.

The Secretary. Mr. Main was unable to be present to-day and has sent the following report of progress:

January 12, 1909.

Your committee desires to report progress. Return postal cards have been sent out to about one hundred and twenty-five members of the Association who had not been previously heard from, with the expectation of being able to get information concerning water and water power diversion awards from many of these members, and a few additional cards were sent out later. Of these there have been about seventy-five cards returned, about fifty of which stated that the signer could furnish no information and about twenty-five contained some information or suggestion.

There have also been sent out to such members as it was thought could give detailed information, blanks covering the data which the committee desires to obtain. Up to the present time only two of these blanks have been filled out and returned.

It would be useless for your committee to attempt to make a report until a large number of these blanks has been filled out and returned. After a number has been returned, the committee will tabulate the returns and prepare them in some form for presentation to the Association, together with such deductions as can be made from them.

CHAS. T. MAIN,
Chairman of the Committee.

The President. It is to be hoped that there will be a general response to the postal cards sent out. The committee is working hard to gather all the information obtainable on this subject, and the help of the members is certainly due to its efforts.

The next matter in order is the report of the committee to gather statistics relating to the depth at which water pipes are laid, and the resulting experience with frozen pipes. Mr. Stacy will read a communication from Mr. Frank A. Barbour, chairman of the committee.

DEPTH OF WATER PIPES.

Mr. George A. Stacy. I have been requested to read a communication from Mr. Barbour, who is not able to be present.

Boston, Mass., January 13, 1909.

Mr. Willard Kent, Secretary New England Water Works Association, Tremont Temple, City:

Dear Sir, — I regret that an engagement prevents my making this report of the Committee on the Depth of Water Pipe personally at the meeting of the Association to be held to-day.

Nothing more than a statement of progress to date can be presented at the present time. Over three hundred copies of the circular have been sent out to members of the New England and American Water Works Associations, these circulars being sent to the superintendents of plants and such engineers as from our knowledge of their work appeared likely to be able to respond with information of value. The circulars were sent out the latter part of December and up to the present time about twenty-five replies have been received. From these replies it is obvious that the information to be obtained from the circulars will be largely negative in character and that in order to obtain information in regard to actual cases of freezing, a personal appeal must be made to engineers and superintendents who have had such experience.

Yours truly,

F. A. BARBOUR.

In connection with this matter, Mr. President, which is an important one, as are also those that the other committees have under consideration, let me say that the value of the work of this committee is dependent largely on the response which the members of the Association make to the circulars sent out. The great value of our Journal, it seems to me, is in its record of the experiences

that we have had in water-works construction and management, and our progress, if we do make progress, is largely due to the application of the experience of others to situations in which we may be placed. So I think you owe it to the members of the Association and to this committee to make replies to the inquiries which have been sent out. It is not necessary in order to do this that you should have a technical knowledge of some deep subject or of some intricate mathematical or astronomical instrument. You have all had a little touch of frost somewhere, and that, as I understand it, is what the committee wants to find out about. Put it in the simplest form that you can. If you cannot remember the exact details, give your experience as fully as you can; it will be a help to the committee and it may be of great help to us. And so, in behalf of the committee, while I have not been solicited to do so, but having served on committees myself, I appeal to you, gentlemen, to reply to the circular as fully and as speedily as you can, in order that we may have a report from the committee which will be of value to the JOURNAL and to the Association.

MR. CHARLES W. SHERMAN. Mr. President, if I may add a word to Mr. Stacy's appeal, I want to suggest that members of the Association, whether they have had any experience in this matter themselves or not, can perhaps send to the chairman of the committee the names of water-works men, who may not be members of the Association, but who can contribute information of value along this line. My own personal experience has not been such as to enable me to furnish any information to the committee, although I received a blank, but I happened to know a gentleman, not a member of the Association, who had a considerable amount of information, to whom I forwarded the blank, and I am glad to say that this morning I received it back from him filled out.

THE PRESIDENT. I think the remarks of the last two speakers are very timely and forcible. I trust that the members will follow out their suggestions fully.

The next matter is the report of the committee to compile information in relation to awards that have been made in water-works valuation cases. Mr. Desmond FitzGerald, I believe, is chairman of the committee. As he is not present, is there any one here who has anything to say for the committee?

AWARDS IN WATER-WORKS VALUATION CASES.

Mr. John C. Chase. Mr. President, I happen to be a member of that committee, and I can report to a limited extent. Some few days after the committee was appointed I received a communication from a member suggesting that we elect Mr. Desmond FitzGerald chairman, to which I cheerfully assented. I heard nothing more until about two months ago, when I had a letter from Mr. Allen Hazen stating that Mr. FitzGerald had positively declined to serve, and that he had been substituted as chairman, and asking my assent to a certain report, or suggesting that the matter had been thoroughly covered by a paper or report which had been presented to another body, and that we use that as our report. I assented to it, with some suggestion of modifications, that perhaps we ought to report something which did not refer to a certain paper. Mr. Hazen said that he positively would not serve as chairman, and suggested the appointment of some one else — I cannot recall at this moment just who — and that is all I can tell you about the committee now. I have had no further communication. I think, however, if the committee is granted further time, that in due time something will be heard from it.

(The following report was received too late to be presented at the meeting.)

REPORT OF COMMITTEE TO LOOK AFTER AND KEEP TRACK OF LEGISLATION AND OTHER MATTERS PERTAINING TO THE CONSERVATION, DEVELOPMENT, AND UTILIZATION OF THE NATURAL RESOURCES OF THE COUNTRY.

The chairman begs leave to report as follows:

The movement for the conservation of the natural resources of the country has been so fully reported in the daily, literary, and technical press that only a very brief summary seems desirable here, and that chiefly for purposes of record.

Two great conservation conferences were held at Washington during the past year, on the initiative of the President of the United States. There has also been held a conference of New England governors, and I believe the governors of some of the other portions of the country have got together on this subject. Some of the engineering societies have given careful consideration to conservation matters. At a meeting of this Association held at Atlantic City last September, papers on some of the conservation features of water and forests were presented, through the agency of your committee.

Besides the large national commission on natural resources, several of the states of the Union have appointed conservation commissions, in accordance with recommendations adopted at the White House Conference of governors last May.

What can this Association do to further so worthy a cause? Just at present the chairman would suggest nothing specific for the Association as such to do except to continue to hold itself ready to coöperate with other associations or bodies engaged in conservation work. The chairman also begs to suggest, as perhaps of far more promise if carried out, that each member contribute his part, individually and through any municipal bodies or private companies with which he may be connected, toward the actual work of conservation. This may be done by continuing the campaign against water waste and for wise utilization of water resources, and also by practicing an intelligent economy in the use of the metal, coal, and timber supplies of the country. Coal, in particular, affords a great field for saving, as every one knows who is familiar with the careless and inefficient way in which it is burned at many water-works pumping stations.

After water and wood, the greatest chance for the members of this Association to give practical every-day aid to conservation work is perhaps in connection with forest products. As a rule this opportunity does not pertain to the use of forest products so much as on their increase by planting and their improvement and conservation by care of forests on water-works drainage areas. Already a considerable amount of forestry work of this kind has been done, but the opportunities, instead of being exhausted, are hardly as yet entered upon. Whatever one's opinions may be as to the recently much-discussed question of the relation between forests and stream flow, probably all will agree that planting trees on water-works drainage areas would be beneficial to public water supplies in more ways than one, besides putting to profitable use land which is necessary for the sanitary protection of water supplies, but which otherwise could scarcely be made to produce a revenue. Of course any revenue of this kind will not become available for years to come. It is for this reason that recourse must be had chiefly to governmental agencies for the planting of forest trees.

Perhaps it will be appropriate to raise the question here why there has thus far been so little development of water-power or hydro-electric power in connection with public water supplies. Such opportunities do not present themselves, by any means, to every water-works authority, but there have been several notable opportunities of the kind which for some mysterious reason have not been seized. The studies of available water-power which have recently been undertaken by the New York State Water Supply Commission in connection with water storage and flood prevention are worthy of careful attention in other states. It is high time that our commonwealths realized that in the water of their streams and lakes they have a valuable business asset for future generations. It may be noted at this point that the act creating the present State Water Supply Commission of New Jersey provides that the state shall receive a revenue for all water taken for municipal purposes in

excess of one hundred gallons per capita per day, the rate to be fixed in each by the commission at a price of $1 to $10 per one million gallons.

Finally it may be noted that there can be no intelligent conservation of anything without knowing the exact nature and extent of that thing. It would seem that a new census of water power, and also a timber census would be highly useful, and that one or both of these might be properly advocated, either now or in the near future, by this Association. Perhaps more important than a water-power census is the securing of more extended and accurate records of everything pertaining to the yield of surface and underground waters.

M. N. BAKER, *Chairman.*

THE PRESIDENT. It seems to be necessary that all the committees should be granted further time, and it is willingly done.

ELECTION OF OFFICERS.

Mr. R. C. P. Coggeshall, in behalf of the tellers appointed to canvass ballots for officers for the ensuing year, submitted the following report:

BOSTON, MASS., January 13, 1909.

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — Your committee appointed by your President to open, verify, assort, and count the ballots cast for officers of this Association for the year 1909 have attended to the duty assigned them, and beg leave to report the following as the result of their canvass:

Whole number of ballots verified	250
Complete blanks	7
For President.	
ROBERT J. THOMAS	238
M. N. BAKER	1
E. W. KENT	1
For Vice-Presidents.	
GEORGE A. KING	235
WILLIAM F. SULLIVAN	232
GEORGE A. STACY	232
ALLEN HAZEN	238
WILLIAM C. HAWLEY	231
ERMON M. PECK	233
LEONARD METCALF	1
F. P. STEARNS	1
For Secretary.	
WILLARD KENT	243

For Treasurer.

Lewis M. Bancroft	242

For Editor.

Richard K. Hale	237
Charles W. Sherman	1

For Advertising Agent.

Charles W. Sherman	240
Richard K. Hale	1

For Additional Members of Executive Committee.

George W. Batchelder	236
Frank L. Fuller	233
Edmund W. Kent	237
E. C. Brooks	4

For Finance Committee.

George Cassell	239
John C. Chase	239
Hugh McLean	238

Respectfully submitted,

R. C. P. COGGESHALL.
F. J. GIFFORD.

The President declared the officers elected, and then extended to Mr. Thomas, the new President, his personal congratulations and presented him to the Association.

Mr. Thomas. *Mr. President and Gentlemen:* I thank the members of the Association for this mark of their confidence and esteem in electing me President for the coming year. I assure you that I deeply appreciate the honor and promise to serve you to the best of my ability.

Mr. M. F. Collins. I move a vote of thanks be tendered to the retiring President for the able, courteous, and impartial manner in which he has presided over our meetings during the past year.

The motion was put by Mr. Thomas, the President-elect, and was adopted with applause.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, February 10, 1909.

The President, Robert J. Thomas, in the chair. The following members and guests were present:

Members.

S. A. Agnew, L. M. Bancroft, G. W. Batchelder, J. E. Beals, F. D. Berry, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, E. C. Brooks, J. C. Chase, J. H. Child, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. O. Doane, John Doyle, E. D. Eldredge, C. R. Felton; J. H. Flynn, F. F. Forbes, W. E. Foss, F. L. Fuller, C. W. Gilbert, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, D. A. Heffernan, J. L. Howard, C. L. Howes, M. F. Hicks, F. M. Hutchinson, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, C. F. Knowlton, A. A. Knudson, N. A. McMillen, A. E. Martin, John Mayo, A. S. Merrill, F. E. Merrill, G. F. Merrill, William Naylor, F. L. Northrop, O. E. Parks, E. M. Peck, H. E. Royce, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, W. E. Smith, J. T. Stevens, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. K. Walker, L. R. Washburn, J. C. Whitney, F. B. Wilkins, G. E. Winslow, W. H. Richards, — 74.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by H. L. Bond and G. S. Hedge; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; F. H. Hayes Machinery Company, by F. H. Hayes; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Chas. Millar & Son Co., by Chas. F. Glavin; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; United States Cast-Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. W. Van Winkle. — 20.

Guests.

Mayor George H. Brown, of Lowell, Mass.; H. N. Ward, superintendent, Newport, R. I.; Edwin L. Burnap, superintendent, and Shepard B. Palmer,

engineer, Norwich, Conn.; N. F. Putnam, Street Department, Lowell, Mass.; Michael Doren and Eugene F. Proctor, Brookline, Mass.; Joseph W. Cowles, Wm. H. Lott, and F. Elwood Smith, Edison Electric Illuminating Company, Boston, Mass.; George R. Stetson, New Bedford, Mass.; John Gray Manuel, assistant superintendent, Natick, Mass.; O. L. Lunn, Beverly, Mass.; R. L. Whipple, assistant city engineer, North Adams, Mass.; Wm. Jameson, water commissioner, Chicopee, Mass.; Mr. Cook, state forester assistant, Boston, Mass.; H. Richards, New London, Conn. — 18.

The President. We have as a guest here to-day a man of whom you have all heard or read about, especially those of you who belong in Massachusetts. You have read about the campaign he made for mayor in a certain one of our cities; how, without political experience and without funds, and in the face of an antagonistic press, he was elected by a larger vote than any candidate ever got before for mayor of that city. Since he has been mayor he has shown, although never having held municipal office before, a wonderful grasp of city affairs, and he has shown unmistakably, what many public officials lack, the courage of his convictions, and the courage to put his convictions into execution. It gives me great pleasure to introduce to you to-day the Hon. George H. Brown, Mayor of Lowell. [Applause.]

Mayor Brown. *Mr. President, Members of the New England Water Works Association, and Guests:* I assure you that it gives me great pleasure to be present here to-day. When my friend your president invited me to come, I said, "You are not going to ask me to make an address, are you?" "Well," he said, "we will let you out easily; you can just say you are pleased to be there and thank them very much."

But he gave me one thought when he said just now that I had the courage of my convictions. I believe that the chief executive of any city, and not only the chief executive, but the other city officials, — you gentlemen who represent your departments in the different cities, you who are the heads of those departments, — that it is necessary for you to have the courage of your convictions. I have had what you may term a common education, and I have those other qualifications which the average man has who runs for public office; but beyond that I feel that I am wholly lacking. But there is one thing I have in my mind, and that is to

do my duty faithfully and to have the courage of my convictions all the time. I had an honest purpose when I went out before the citizens of my city and asked them to elect me as their chief executive, and I said, "If you elect me as your mayor I will do so and so"; and as the mayor, and as the servant of the city of Lowell, I am trying to put into force what I promised. I said to the people of Lowell, "If you will elect me as your mayor, I will never betray you," and as their mayor I am not going to betray the trust which was reposed in me when I was elected to the high office of chief executive of the city of Lowell.

So I say to you to-day, gentlemen, do not betray the trust that is reposed in you; have the courage of your convictions all the time; have an honest purpose, taking for your pattern our martyred President, the one hundredth anniversary of whose birth we will celebrate on Friday. Do your duty faithfully and honestly, as Lincoln did his. The men who do their duty and have the courage of their convictions wear well and will wear all the time. I haven't any peculiar ability. They tell me that throughout the state of Massachusetts and in other places people read about Brown; but Brown has no exceptional qualifications; he has no real ability. All Brown has got is the courage of his convictions and an honest purpose, and he is trying to do his duty; that is all. So you see that if a man tries to do his duty he wears well, he wears all the time, like our honored President Roosevelt, who wears well and will continue to wear well. So all men who are acting in an official capacity, if they do their duty, they will wear well and will be remembered; but when they fail to do their duty, when they betray the trust of the people, they will be forgotten.

I am much interested in one of the topics you have on your program — the grounding of electric light wires on water pipes. We have that in Lowell. I had the head of the electric light company in Lowell in my office the other day, and I called his attention to this matter. I said to him, "We want better service from your corporation." He went into the cost of furnishing that better service, and I said, "There will be no cost to the city; it is going to be free from your corporation. Lowell is giving you and has been giving you quite a consideration in letting you ground your wires on our water pipes, and you have got to give us better service. You have got to give us what we want, and if you do not,

I will see to it that you don't ground your wires on our pipes any longer." I am not going into the matter any further, and I only mention this to let you know that I am interested in the subject in Lowell, and I had that in mind more than anything else in coming down here, for I wanted to get some information upon this subject. I am not a good speaker, as you have discovered; I think I am a better listener. I thank you.

The President. After listening to the Mayor of Lowell you may think that I had a lot of presumption to tell him what to say. [Laughter.] You undoubtedly are all satisfied that he knows just what to say and how to say it. We will now proceed with the business of the meeting, and the first matter is the consideration of applications for membership.

The Secretary read the names of the following applicants for membership, all of whom had been duly approved by the Executive Committee:

Karl H. Hyde, civil engineer, Attleboro, Mass.; Warren E. Tarbell, East Brookfield, Mass., water commissioner, Brookfield; Frank L. Rector, Brooklyn, N. Y., bacteriologist, Great Bear Spring Company, Brooklyn, N. Y.; J. P. A. Laforest, Levis, Canada, engaged in water works construction; William Sinclair Bacot, Morristown, N. Y., formerly water works engineer and manager, but not in active practice at present; A. P. Negus, New Bedford, Mass., pumping engineer of the New Bedford Water Works Department.

On motion of Mr. Coggeshall, the Secretary was directed to cast one ballot in favor of the applicants, and he having done so they were declared elected members of the Association.

There were two papers on the program for the afternoon, the first on "Lead Covered Cables a Cause of Electrolysis of Water Pipes," by A. A. Knudson, electrical engineer, New York City; and the second on "Grounding Electric Light Wires on Water Pipes," by Frank E. Merrill, water commissioner, Somerville, Mass. Mr. William H. Lott, Superintendent of Right of Way and Street Lighting of the Boston Edison Electric Illuminating Company; Mr. Joseph W. Cowles, superintendent of installation, and Mr. F. Ellwood Smith, also of the Edison Company, were present as guests of Mr. Merrill, and spoke upon the matter presented in

Mr. Merrill's paper, and answered numerous questions which were asked by members of the Association.

The President extended the thanks of the Association to the officials of the Edison Company for the information which they had given, and expressed his pleasure at the large attendance.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 9, 1908, at 11.30 A.M.

Present: President Alfred E. Martin, and members Michael F. Collins, George A. Stacy, Lewis M. Bancroft, George A. King, George W. Batchelder, Robert J. Thomas, Charles W. Sherman, William F. Sullivan, and Willard Kent.

The following applications were received and recommended for membership, viz., O. C. Merrill, civil engineer, Berkeley, Cal., and John C. Otis, M.D., president Board of Public Works, Poughkeepsie, N. Y.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 13, 1909.

Present: President Alfred E. Martin, and members D. N. Tower, George A. King, Robert J. Thomas, Michael F. Collins, George W. Batchelder, George A. Stacy, Charles W. Sherman, William F. Sullivan, Lewis M. Bancroft, and Willard Kent.

The following applications were received and recommended for membership, viz.:

For members: Herbert D. Pease, director New York State Hygienic Laboratory, Albany, N. Y.; Arthur E. O'Neil, superintendent pumping stations, Metropolitan Water Works, Watertown, Mass.; Millard F. Hicks, treasurer Portland Water District, Portland, Me.; Leonard M. Wachter, sanitary chemist, New York State Department of Health, Albany, N. Y.; Charles H. Tuttle, superintendent Bristol and Warren Water Works, Bristol, R. I.; Fred M. Hutchinson, engineer and foreman water works, Somerville, Mass.

For Associate: F. H. Hayes Machinery Company, pumping machinery, Boston, Mass.

Voted: That a committee of three, not members of the Executive Committee, be appointed by the President to investigate hotel accommodations with a view to improvement.

Voted: That the Executive Committee be and hereby is made a reception committee to welcome new members and visitors.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, February 10, 1909, at 11.30 A.M.

Present: President Robert J. Thomas, and members George A. King, William F. Sullivan, Ermon M. Peck, George W. Batchelder, Frank L. Fuller, Edmund W. Kent, Lewis M. Bancroft, Charles W. Sherman, and Willard Kent.

Six applications were received and recommended for membership, viz., J. P. Albert Laforest, civil engineer, Levis, Canada; Frank L. Rector, M.D., bacteriologist, Brooklyn, N. Y.; Warren E. Tarbell, water commissioner, Brookfield, Mass.; Karl H. Hyde, civil engineer, Attleboro, Mass.; A. S. Negus, pumping engineer, New Bedford, Mass.; and William Sinclair Bacot, civil engineer, Morristown, N. J.

The subject of place for holding the next annual convention was discussed. The committee to ascertain accommodations at Bangor made informal report, and Mr. Ermon M. Peck was made a committee to make similar investigations with reference to New Haven, Conn.

Messrs. Charles W. Sherman, Richard K. Hale, and William E. Maybury were constituted a committee to arrange for the June excursion.

The committee on hotel accommodations reported that they have made satisfactory arrangements for service, and recommended that a committee be appointed to see that those arrangements are carried out. Mr. George W. Batchelder was made that committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Edwin Reynolds died at his home in Milwaukee on February 19, 1909.

Mr. Reynolds was born in Mansfield, Conn., on March 23, 1831. He was the son of Clarissa Huntington and Christopher Reynolds, and a direct descendant of William Reynolds, who came from Gloucestershire, England, in 1673, settling in Rhode Island.

Mr. Reynolds, after leaving the public schools, became an apprentice to a machinist. Later he worked in machine shops in Connecticut, Massachusetts, and Ohio, finally becoming superintendent of the machine shops of Steadman & Co., of Aurora, Ind., after which he again returned to Connecticut. He remained for six years in that state as well as in Boston and New York, during which time he worked on the machinery of Ericsson's *Monitor*, which played such an important part in the Civil War.

After the war he entered the Corliss Steam Engine Company, of Providence, R. I., and in 1871 was made general superintendent of that company.

In 1877 he left the Corliss Company to work with Edward P. Allis & Co., of Milwaukee. Later, on the reorganization of that company, he became director, vice-president, and general superintendent. This position he held until 1901, when he became director and chief engineer of the Allis-Chalmers Company, which was organized largely through his efforts.

He retained this position until 1906, when, his health failing, he had to give up active business, though still keeping his title of chief engineer.

Among some of Mr. Reynolds's designs are the Reynolds-Corliss valve gears used by every builder of Corliss engines; a direct-acting metallic valve blowing engine, which revolutionized the construction of blowing engines and air compressors; and a steam stamp for

crushing ore. Mr. Reynolds also designed some of the largest hoisting engines in the country.

The modern "high-duty" triple expansion pumping engine was another design original with Mr. Reynolds. At present this represents universal practice, but at the time it was introduced it was a radical departure from the type of machinery then in use.

Mr. Reynolds designed many of the large engines for electrical work, among which may be mentioned the 12 000 horse-power engines of the New York subway and Manhattan elevated power stations.

Mr. Reynolds was president of the American Society of Mechanical Engineers in 1901 and a member of the Executive Committee of the same society. He received a degree of LL.D. from the University of Wisconsin.

Mr. Reynolds was elected an honorary member of the New England Water Works Association on September 13, 1906.

BOOK REVIEW.

Laboratory Notes on Industrial Water Analysis. A Survey Course for Engineers. By Ellen H. Richards, Instructor in Sanitary Chemistry, Massachusetts Institute of Technology. iii + 49 pages. 6 x 9 inches. New York: John Wiley & Sons. Cloth, 50 cents net.

This little book is presented in the form of laboratory exercises, showing in condensed form the procedures of water analysis.

The author classifies water into three main divisions, — scale forming, moderate scale forming, and non-scale forming, — and offers the simpler tests for placing the water under examination in one of these groups; after that follows the procedure for the more exact methods of determining the constituents of the sample.

To an engineer who has a slight knowledge of chemistry, this book offers in a condensed form the standard methods used for determining the kind and quantity of the more important substances in a water, that are injurious to boilers.

To the student the book gives a condensed survey of a subject which undoubtedly will be of value to him in his future practice.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXIII. June, 1909. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

NOTES ON NEWTON, N. J., WATER WORKS CONSTRUCTION AND LITIGATION.

BY LOUIS L. TRIBUS, MEMBER AMERICAN SOCIETY CIVIL ENGINEERS; MEMBER NEW ENGLAND WATER WORKS ASSOCIATION.

[*Read December 9, 1908.*]

In 1894 the town of Newton, situated in the semi-mountainous region of the northwestern part of New Jersey, took up very actively the question of a public water supply. Rain water cisterns, shallow dug wells penetrating slightly into the slate rock, and an occasional driven or bored well but partially served the general needs of the community. An active contest was waged between interests desiring municipal ownership and those either wishing to secure a franchise or preferring that one be granted.

Early in the proceedings the writer was called upon to advise various committees, and later, when final decision called for municipal construction, to design the works and carry them to completion, and from time to time since then, to take up matters of operation and litigation.

Three sources of supply seemed possible: first, a driven-well pumping system close to the town, but subject to risk of contamination as the town developed; second, a lake of rather hard water, some four miles away, for which, also, pumping would be necessary. The third, recommended by the writer, and finally adopted, was Morris Lake, situated about eight miles in an air line from Newton, in depth from eight to one hundred and ten feet, somewhat increased over natural capacity by a low dam, and the

NOTE. — Among the illustrations in this paper occur a number reproduced through the courtesy of the *Engineering Record.*

surface at such an elevation as to permit of a flow by gravity and give a good serviceable pressure in all parts of Newton except one small high point and a portion of another hill lying chiefly outside the town limits. (Fig. 1.)

The source of supply thus selected was well-nigh ideal; a soft water; an uninhabited, mountainous, 85 per cent. wooded watershed (Fig. 1, Plate I). Unfortunately, however, for legal reasons, the lake was not tributary to a stream passing the town of Newton, but to one flowing in a different direction, so that Newton had no standing as a riparian owner.

The writer urged very strongly upon the Water Commissioners an amicable settlement with the mill owners on the stream below the lake before any work should be carried out, a settlement that could have been readily effected for a few hundred dollars apiece, probably not aggregating over two thousand dollars at the outside. Coupled with that advice it was still deemed advisable to provide increased storage facilities in Morris Lake, so that from storm flows alone there could be impounded an abundance of water for the needs of the town and thereby not interfere with the normal ordinary flow from the lake.

To this latter end a small brook, not entering the lake, but joining its outlet, far above the first mill (Titman's), was diverted by a masonry head gate (Fig. 2, Plate I) into a side hill ditch or canal (Fig. 1, Plate II) some three thousand feet or so in length, reaching a point just above the masonry dam, which was constructed at the outlet of the lake proper, at a site almost perfect for the purpose — a narrow neck with rock sides and bottom. To provide the additional storage, the dam was constructed of such a height as to raise the normal level of the lake about five feet, giving a flooded area of 155 acres, and in addition flash boards could be placed in the spillway, adding another two feet if desired. The total storage above the lower outlet thus secured amounted to 730 000 000 gallons, while the storage above the original normal high-water mark amounted to 208 000 000 gallons (Fig. 2, Plate II, and Fig. 1, Plate III).

As the combined watersheds thus made available equaled about three and one-half square miles, the estimated draft of 1 000 000 gallons per twenty-four hours could be easily provided several

Fig. 1.

NEWTON N. J. WATER WORKS

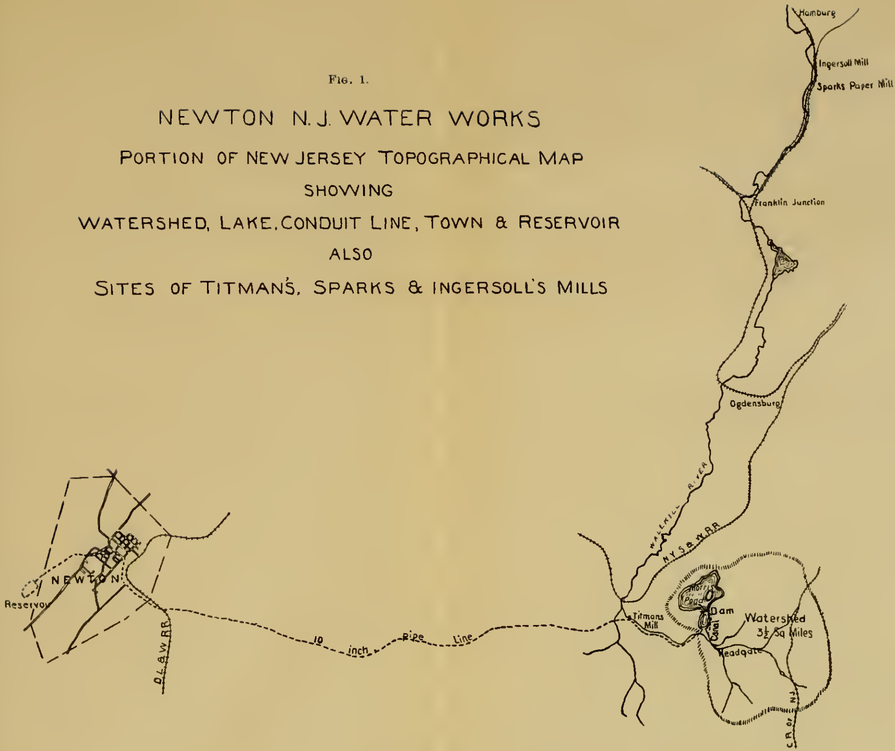
PORTION OF NEW JERSEY TOPOGRAPHICAL MAP

SHOWING

WATERSHED, LAKE, CONDUIT LINE, TOWN & RESERVOIR

ALSO

SITES OF TITMAN'S, SPARKS & INGERSOLL'S MILLS



times over during the year from storm waters, which could not have been used through any existing developments by any mill on the stream (a tributary of the Wallkill River).

The Water Commission purchased the fee in Morris Lake (though not in the pond below the lake) and in a sufficient strip surrounding it to give reasonable protection and access; but in purchasing some of the land owned by the mill owner (J. B. Titman) next below the lake there was reserved to him the right to operate the gates in the artificial pond at the outlet of the main lake that had been in existence for many years and which because of the breaking down of an old dam between them had been, for a period, a part of it.

In the agreement, the town also bound itself to open the gate in the masonry dam so as to keep up the water level in the lower pond, thus practically leaving the control of the outflow in the hands of Titman, who had first right to use the waters, and who for many years had thus used the outflow from the lake and pond as he chose, without reference to any mill owners further down stream. Those lower owners had no pondage to do other than to steady the head upon their water wheels and, consequently, could not regulate the flow of the stream to any real extent for their own benefit, and also they had no special rights in the lake's storage or in control of its outflow.

Construction was carried on as previously outlined, without any formal objection from any mill owner. As a matter of fact, the mills were greatly benefited by the work done, for by the conservation of the storm waters, in excess of those which Newton could use, the stream flow was steadied, thus better meeting the needs of the mills than was possible prior to the construction.

The Water Commission did not take the advice of its engineer as to making agreements with the different mill owners, so that after the work was completed and the town was being supplied with water, several suits for damages for diversion of water were instituted, and these suits were pressed to final decision, the court of last resort, that of Errors and Appeals, confirming the decision of the Court of Chancery as to the principle involved, that payment must be made in money, as liquidated damages, instead of in kind, with water, but reversing the decision as to amount of

awards, cutting them down from $3 180 to $500 in one case, and from $3 962.40 to $750 in the other. The whole litigation, however, entailed an expense upon the town many times greater than would have been the case if preconstruction agreements had been entered into.

Early in 1902, J. B. Titman, the mill owner from whom the town had purchased some lands and rights, and to whom the privilege of gate opening had been accorded, as before noted, also brought suit for damages.

After litigation lasting several months, involving the attendance at the trials of many witnesses (experts and others), the case was compromised out of court by the town agreeing to pay said Titman $5 500, receiving in return full control of the lake and Pine Swamp Brook (the one diverted to augment the Morris Lake supply) and use of all water which could flow through the existing 10-inch pipe line to Newton, and further agreeing to be careful in letting out the surplus lake waters, so as not to cause injury to the dam at lower end of pond adjoining the lake, and also to permit Titman to raise said earth dam up to within 4 feet of the level of the spillway in the masonry structure erected by the town.

Fig. 2, Plate III, shows the wastage of water from Titman's mill and the extravagant drafts he made on the stream and stored waters, after he contemplated bringing suit for damages, trying to create a shortage in storage, and show his great deprivation of water, presumably due to the town's use of it.

The main pipe line, 10 inches in diameter, was laid on an acquired right of way in as nearly as possible an air line, two or three summits being encountered, as may be noted on the profile (Fig. 2), where air valves were deemed advisable. At one place the summit

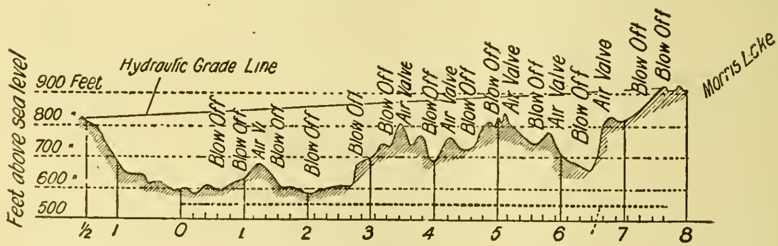


Fig. 2.

FIG. 1.

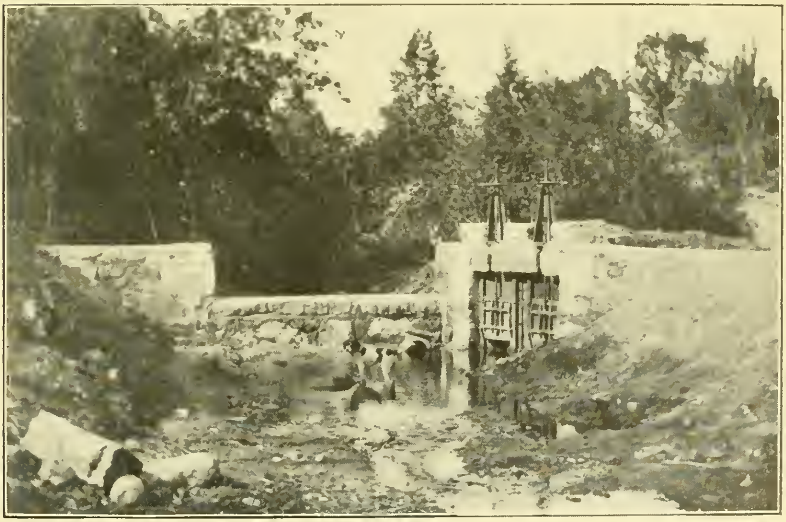


FIG. 2.

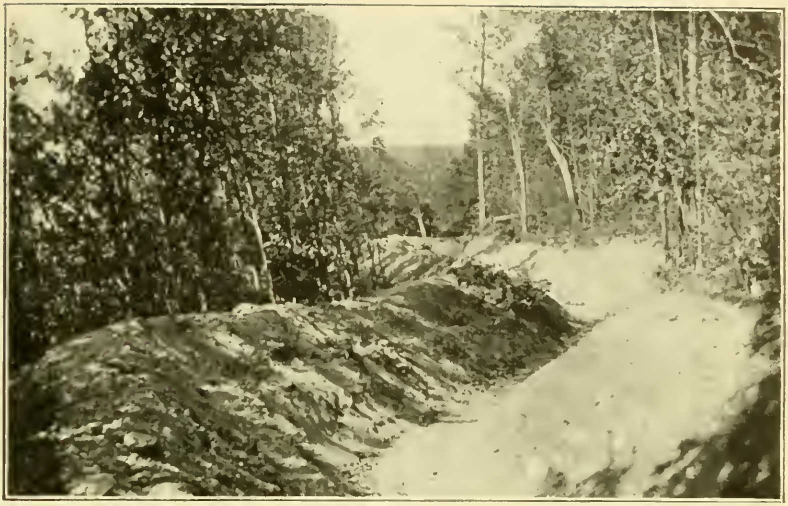


FIG. 1.

FIG. 2.

FIG. 1.

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FIG. 1.

FIG. 2.

so nearly approached the hydraulic grade line (taking the elevation of assumed average draft), as to become the controlling factor in the calculated flow of the main, as brought out in the court proceedings. The writer protested against laying any main less than 12 inches in diameter and urged the securing of rights of way, for later duplicating the line, if necessary, but the commissioners in their wisdom thought the ten or twelve thousand dollars' extra cost of the larger pipe prohibitive and the securing of additional rights unnecessary. Time has already demonstrated the wisdom of the engineer's advice, for the 10-inch main is well-nigh overtaxed, and needed rights for another main will require additional payments, while the water for the extra draft will have to be paid for by a new crop of damage suits, or through agreements to be entered into prior to its construction.

Though contemplated in the original scheme, the reservoir in the town was not constructed until 1905, when the draft had increased to such an extent as to make a twenty-four-hour flow necessary. This reservoir provides in its six or seven million gallons storage some little reserve in case of pipe line accident or stoppage, and secures a steadier fire service (Fig. 1, Plate IV).

DETAILED DESCRIPTION OF PLANT.

The two lakes meet at a narrow strait, having a rock bluff at one side and a sloping rock ledge on the other. An old crib dam had formerly been in use, but years ago it was partially demolished. The rock banks met at a point 30 feet below the new high-water mark, or 33 feet below the top of the masonry, without injurious seams or cracks. The site could not have well been more advantageous, enabling a dam to be built only 150 feet long on the crest, with but 25 feet of it having any considerable depth.

Fig. 3 shows the general plan of headgate, canal, pond, lake, standpipe, and submerged outlet conduit.

The head-gate works for controlling the diversion canal consist of a small masonry dam and overflow weir, having two 24-inch gates opening into the canal. These openings will pass all of the normal and much of the flood season flow of the stream, and are located on Pine Swamp Brook about three thousand feet from and fourteen feet above the upper lake.

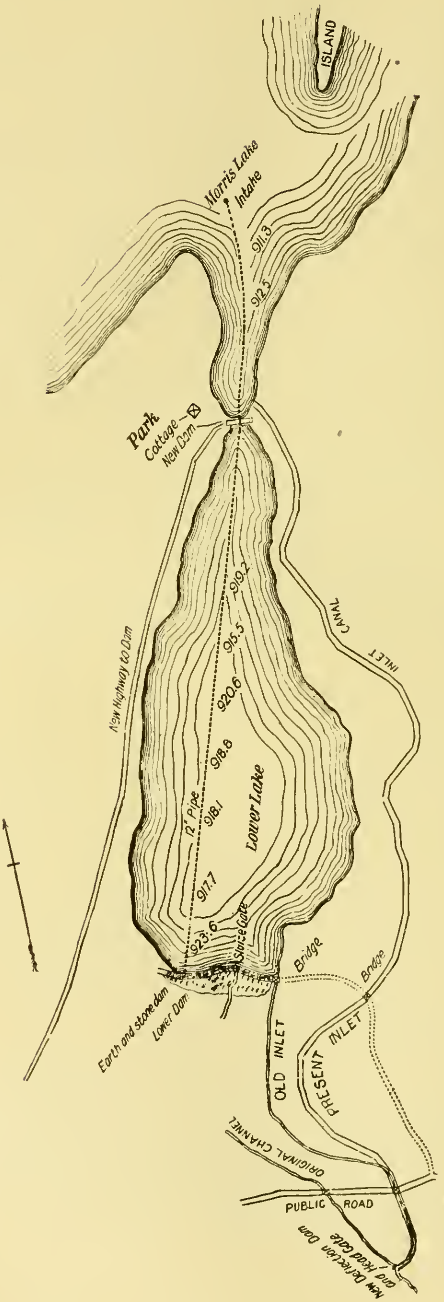

ISLAND
Morris Lake
Intake
911.3
912.5
Park
Cottage
New Dam
919.2
915.5
920.6
918.8
918.1
12" Pipe
Lower Lake
917.7
923.6
Sluice Gate
New Highway to Dam
CANAL
INLET
Bridge
Bridge
Earth and stone dam
Lower Dam
OLD INLET
PRESENT INLET
ORIGINAL CHANNEL
PUBLIC ROAD
New Deflection Dam
and Head Gate

Fig. 3.

The deflection canal is 3,000 feet in length, following the general contour of the hill. It is 4 feet wide at the bottom, $2\frac{1}{2}$ feet deep to the water run, and has slopes of $1\frac{1}{2}$ to 1 in earth and $\frac{1}{8}$ to 1 in rock. The canal was constructed in excavation entirely, so that the water run is everywhere in natural ground; the grade is 5 inches per 100 feet.

A timber cofferdam, about eight feet in width by nine feet in depth by sixty feet in length, was first built across the strait, 15 feet above the toe of the new dam, inclosing the end of the 12-inch effluent pipe, and provided with a 12 by 12-inch sluice to draw off water for the mills, if required. It was heavily framed, planked on both sides, its bottom shaped to the contour of the lake bed, steadied in place, and still further tightened by a double row of sheet piling driven to hard bottom. Clay and sand filling inside and on the upper lake side made a very tight structure, so that when the lower lake was drawn off and all the pressure came on one side, hand-pumping readily cared for all the seepage.

The main dam was constructed of local stone, a species of granite, laid as rough rubble, with rough dressed copings and spillway, the sand for cement mortar being fine crushed rock from the Edison ore crushing works (Fig. 4). The flow line without flash boards was established at elevation 935 feet above sea level.

Adjoining the site of the dam, about five acres of land was secured for park purposes, and a commodious cottage was erected for the superintendent in charge of lake and conduit.

The conduit line is supplied through an intake standpipe in the lake and a submerged main carried along the bottom of the upper pond, through the masonry impounding dam and along the entire length of the lower pond and through the old dam at its lower end. The intake standpipe consists essentially of a wrought-iron open-ended cylinder $3\frac{1}{2}$ feet in diameter and 38 feet in height, furnished with two 16-inch sluice gates opening at elevations $915\frac{1}{2}$ and $922\frac{1}{2}$, with conical brass screens inside, and connected with the 12-inch effluent pipe at elevation $912\frac{1}{2}$. (Fig 5.) It was made with a reinforced cutting edge in the bottom and is protected by eight piles with cross and diagonal bracing of timber and sheathing, and some one hundred and fifty loads of riprap dropped around the foot.

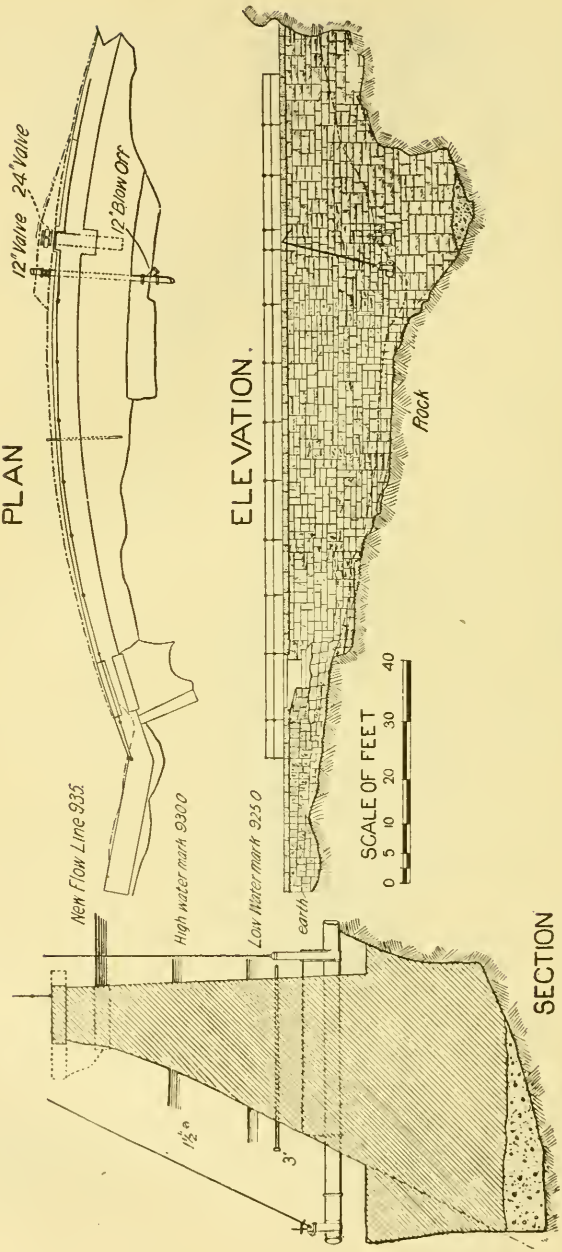

PLAN
12"Valve
24"Valve
12"Blow Off
ELEVATION.
Rock
SCALE OF FEET
0 5 10 20 30 40
New Flow Line 935
High water mark 930.0
Low Water mark 925.0
earth
SECTION
1½"
3'

Fig. 4.

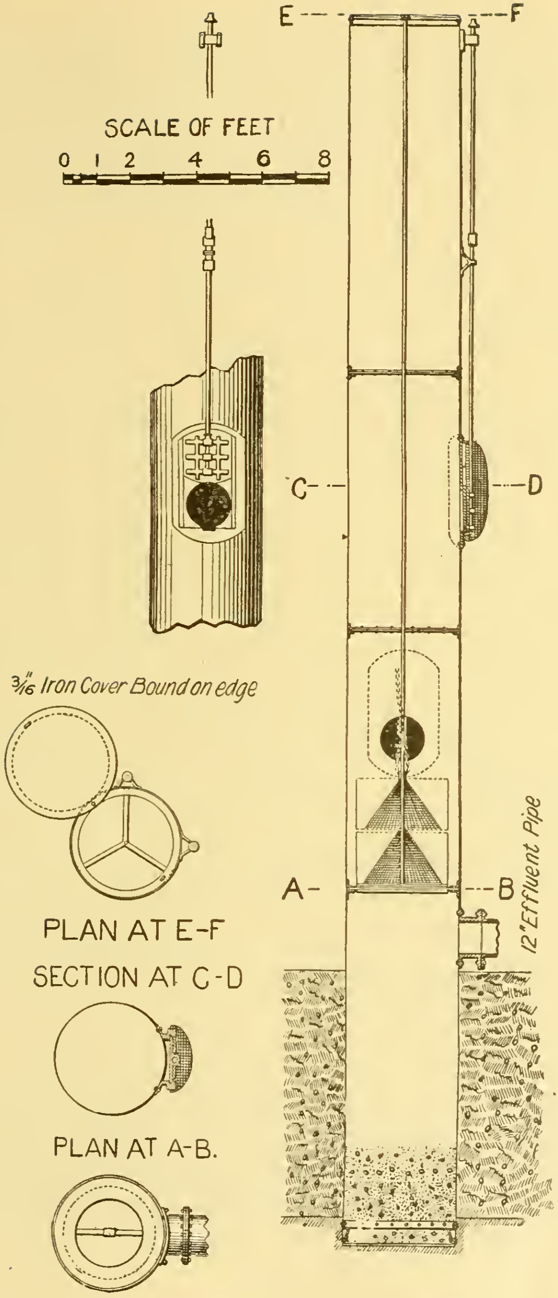

E
F
SCALE OF FEET
0 1 2 4 6 8
C
D
3/16" Iron Cover Bound on edge
PLAN AT E-F
SECTION AT C-D
PLAN AT A-B.
A
B
12" Effluent Pipe

FIG. 5.

Early in January, 1895, the ice having reached 12 inches in thickness, a point was selected (previous soundings having determined the approximate locality) where the silt bottom was 10 feet thick, and hard bottom found at elevation 900. A 40-foot derrick was then erected on the ice, its load distributed by a large plank platform, and the standpipe, bolted together, was raised complete, with 72 feet of 12-inch main attached, and lowered to position through a hole cut for it and a channel for the pipe. Its weight (about eight tons) caused it to sink several feet in the silt, cutting its way through; then by dredging from the inside and weighting, it was sunk into the hard bottom. When all the silt had been removed from the inside, Portland cement concrete was rammed in to a depth of 4 feet, giving additional stability and effectually shutting out all infiltration of silt. The piles were at once placed in similar manner with the derrick, and driven by it also, using a 1 500-pound hammer, with an 8-foot drop, guided by a scantling frame around the hammer long enough to pass down over the pile.

While the standpipe was being lowered, 72 feet of the 12-inch main connected to it was lowered also, in water 20 feet in depth, keeping the free end on top of the ice. To this was attached section after section, 48 feet being thereafter lowered at a time. A Ward spherical joint every 48 feet gave motion enough and rope supports in between kept the sections rigid, until they rested finally on the bottom. The upper lake section was 650 feet in length through the cofferdam. The lower lake section was about fourteen hundred feet to the lower earth dam. The depths ranged from six to twenty feet of water and zero to ten feet of silt. The work itself was very easily done, it being necessary simply to lay the pipe in a straight line on the ice, connect it up with lead joints, make a saw cut through the ice on each side of the line, the ice being from ten to fourteen inches in thickness, and lower the main gradually until it reached bottom, 48 feet at a time. At a later date when, during construction of the dam, the lower lake was emptied, the pipe was found resting easily, with no indications of break or strain. (Fig. 2, Plate IV.) It was thought best then to lower it from two to four feet to provide for a future complete draining of the lower lake, which was done by excavating underneath it and letting it settle.

The whole plant (including distribution system) was put in operation October 1, 1895, and was received from the commissioners by the town of Newton on October 17, 1895. The principal other dates of note were as follows:

December 3, 1894: contracts for

(*a*) Pipe and specials to Warren Foundry and Machine Company.

(*b*) Valves and hydrants to Eddy Valve Company.

(*c*) Intake standpipe to Tippett & Wood.

December 18, 1894: contract for construction awarded to Smith & McCormick, of Easton, Penn.

January 14, 1895: construction begun.

May 8, 1895: contract for highway and bridge to B. H. Titman.

August 31, 1895: water turned into main pipe line.

September 19, 1895: water turned into canal, practically completing the construction period.

Officials connected with the work of construction:

Water Commissioners: Hiram C. Clark, president; Alex. Craig, secretary; A. J. Van Blarcom, treasurer.

Counsel: Chas. M. Woodruff.

Engineers: Louis L. Tribus, chief; Andrew H. Konkle, assistant on preliminary surveys; Chas. G. Massa, assistant on construction, lake division; B. F. Ward, assistant on pipe lines.

The work was completed within contract time, without material deviation from the plans and specifications, and for a total sum about one and a half per cent. less than the engineer's original estimate, the whole plant, without litigation, costing about one hundred and five thousand dollars for rights, lands, construction, supervision, and miscellaneous expenses.

The writer has thought the litigation to be of sufficient interest to warrant the presentation, not of the testimony given, but of the full decision of the court of last resort, which reviewed briefly the facts and gives clearly the argument and dictum:

New Jersey Court of Errors and Appeals, November Term, 1899. The Sparks Manufacturing Company, Respondent, *v.* The Town of Newton, Appellant; Worthington H. Ingersoll, Respondent, *v.* The Town of Newton, Appellant.

(1) When the riparian proprietor seeks the aid of a court of

equity to restrain the diversion of water by a municipal corporation for public purposes, and offers to forego his right to an injunction on recovering just compensation, which he asks the Court to determine, and the defendant in its answer consents to pay such compensation so as to be determined by the Court, in case the Court considers the complainant entitled to an injunction, the Court has jurisdiction to ascertain the amount of such compensation.

(2) A municipality which buys a piece of land on a private stream several miles from its corporate limits does not thereby become entitled as riparian owner to draw from the stream a supply of water for the inhabitants of the town.

(3) The town of Newton has no authority to divert water from private streams, to the detriment of lower riparian owners, on condition that it will store storm water and give it out into the streams in dry times, and thus confer a compensatory benefit on those owners, they not consenting thereto.

(4) In ascertaining just compensation for the diversion of water from a mill, the difference between the market value of the mill before the diversion and its market value afterwards is usually a simpler and safer criterion than estimates of the probable cost of producing by steam at the mill the power which the diverted water would supply and then estimates of the probable value of the water power at the mill, based on the rental value of power at other places more or less distant and dissimilar.

Messrs. W. H. and C. L. Corbin for complainants, respondents; Mr. Thomas Kays for defendant, appellant.

The opinion of the Court was delivered by Dixon, J.

The circumstances of these cases are very fully stated in the preface and opinion of Vice-Chancellor Pitney, 57 N. J. Eq. 367. With the conclusion there expressed touching the power and duty of the Court, on the pleadings and evidence, to fix the compensation that the defendant ought to pay to the complainant as a condition of withholding the injunctions to which they otherwise would be entitled, this Court agrees. Only with respect to the amount awarded do we find reason for dissent.

The right to be obtained by the defendent under these decrees is the right to abstract from one of the tributaries of the Wallkill River a definite quantity of water, which in its natural course would flow past the complainant's mills. The opinion of the vice-chancellor deals with the right to divert 800 000 gallons per day, and this quantity of water is shown by him to be capable of producing 2.54 continuous horse-power at the Sparks Company's mill and 2.65 continuous horse-power at Ingersoll's mill. On

this basis the learned vice-chancellor proceeds with two calculations:

(1) To ascertain the probable annual cost of producing the same power by steam at these mill sites, and (2) to ascertain the probable annual value of the power at these localities, in view of the rental price of such power in other places more or less distant and dissimilar. Having thus formed an estimate of the annual value of the power, he compounds that value at 4 per cent. for forty years and finds the present value to be $3 302 at the Sparks mill and $2 650 at the Ingersoll mill, and, therefore, awards these sums.

In this course of reasoning little, if any, attention was paid to the actual market value of the mill sites, and yet in Packard *v.* Bergen Neck R. R. Co., 25 Vroom, 553, this Court declared that, when only part of a person's property is taken, just compensation will be made by awarding the difference between the market value of the property before any part was taken and the market value of the property after the taking.

While it may be proper in such cases as the present to take into consideration the matters on which the vice-chancellor's award rests, still we deem the difference between market values a simpler and safer criterion; and when it appears that by following other guides a result is reached utterly irreconcilable with this criterion, that result cannot be sustained. That such incompatibility exists in the case before us will be made manifest by a few considerations now to be stated.

The testimony of witnesses living in the neighborhood of the Ingersoll mill and familiar with it for many years is to the effect that the fair market value of the whole plant in 1896 when these bills of complaint were filed was $5 000 or $6 000. It has a total capacity to use 132 horse-power of water, which will be furnished by about 1 100 000 000 gallons of water per month. A tabulated statement of the natural flow of the river at Ingersoll's mill, known in the case as Vermeule's Table D, which appears to have been accepted as trustworthy by all parties at the trial, shows that during eight months of the average year there is more than a sufficient supply of water for the full capacity of the mill, that during June and September the supply is above five sixths of the capacity, and that during July and August the supply exceeds five ninths of the capacity. These data indicate an annual supply equivalent to 118 continuous horse-power at this mill.

Now, if for the abstraction of 2.65 continuous horse-power the mill owner ought to be paid $2 650, then, for the abstraction of the whole power he ought to be paid $118 000. Such an inference proves the extravagance of the award. In April, 1896, the plant of the Sparks Manufacturing Company was purchased by that

company for $75 000. The plant included the water machinery with a total capacity of 170 horse-power, steam machinery having 100 horse-power, mill buildings, and several acres of land.

To run the water plant to its full capacity the company required about 1 360 000 000 gallons of water per month, and beside it used about 30 000 000 gallons per month for condensing steam, washing fabrics, etc. Vermeule's Table D shows that during eight months of the average year there is more than a sufficient supply of water for the full capacity of this water power, that during June and September the supply is about two thirds of the capacity, and that during July and August the supply is about four ninths of the capacity. These data indicate an annual supply equivalent to 141 continuous horse-power at this mill.

If for the abstraction of 2.54 continuous horse-power of water the company ought to be paid $3 302, then for the abstraction of the whole power it ought to be paid $183 300. This inference proves the extravagance of the Sparks Company's award.

We think there is another error in the basis on which the present awards are made. Assuming that the defendant withdraws 800,000 gallons of water per day (i. e., 25 000 000 gallons per month), Vermeule's Table D shows that in an average year after the allowance to the defendant is taken, more water will flow past these mills during eight months than either of the mills can utilize, so that only during four months will the supply available in the mills be perceptibly diminished. During these months the water diverted by the town would furnish 3 horse-power at the mills, and 3 horse-power for four months would be equivalent to 1 continuous horse-power. Thus, even on the assumption that water power at these mills is as valuable as the learned vice-chancellor deemed it to be, allowances for 2.54 and 2.65 continuous horse-power are about two and one-half times too large.

In our judgment an award of $500 to Mr. Ingersoll and of $750 to the Sparks Manufacturing Company will afford ample compensation to them for the abstraction by the defendant of 800 000 gallons of water per day. Under the election by the town to abstract 1 250 000 gallons per day; these sums must be proportionately increased.

Let the present decree be reversed and decrease be rendered in accordance with the judgment above stated.

Notwithstanding this very lucid decision, the writer still holds very clearly to his belief that true justice should refuse to award damages where no actual damage has occurred or can occur, and where real benefit has been created instead. That argument is,

of course, met by the actual fact that water was diverted, so that theoretically the mills were deprived of it, and in light of a constitutional and not parliamentary government, payment can only be made in coin of the realm and must be based on theoretical as well as real injury.

Newton's case was at the time almost unique in the United States, where works of benefit were actually completed and in operation before litigation was begun, so that real damage could not be proven by inference or be shown in fact.

DISCUSSION.

Mr. Charles E. Chandler. At one or two meetings of the New England Water Works Association the question of compensating for diversion in kind, recommended in Norwich by Hill, Quick & Allen, has been referred to. I will read five or six lines which describe just the method in which Hill, Quick & Allen suggested that riparian owners be compensated for water that might be taken by the city. The proposition was to build a large storage reservoir, large enough to be ample for the city's needs with something left for the mill owners, but the actual proposition reads a little differently:

> "Whenever the flow of the Yantic River at any of the mills from the watershed of that river above the mills, exclusive of the 11.9 square miles on Pease Brook, is less than the amount necessary to develop the flow at the mill, water is to be released from the proposed storage reservoir for the benefit of all the mills in quantities equal to the estimated flow of Pease Brook, at that time, but not exceeding the amount of the above deficiency."

That is the whole plan and, as you will see, it does not call for compensating the mills at all, but calls for a delivery to the mills, every day when they are short of water, the exact amount of water, as nearly as can be ascertained, that they would have received if this reservoir had not been built. The mill owners took it into consideration, and, having decided that the plan wasn't likely to go through for other reasons, declined to consider the proposition at all.

Mr. William S. Johnson. There was a case which interested

me very much, and it may interest water-works officials, which came up a few days ago, where a manufacturing company in a certain town was sued by the town for water rates, it being alleged that the company had been stealing water from the department. The result of that suit was that the town was obliged to pay the manufacturing company $100 and court expenses. That seems a little peculiar, but the fact was that the water which had been furnished by the town to the manfacturing company had never been legally taken, but was being practically stolen from the manufacturing company, so you see there the tables were turned. This story carries its own moral.

VICE-PRESIDENT KING. The city of Taunton has had a case very similar to the one of which Mr. Tribus has spoken, and it was on trial last week. In 1875 an act of the legislature was passed which allowed the city of Taunton to take water from the Taunton River or from the Lakeville ponds. We first took it from the Taunton River, and in 1894 we went to the Lakeville ponds for water. The act of 1875 allowed us to take water from the Assowompsett Pond, but only the "surplus waters" of that pond, and required us to build a dam at the outlet, not less than two and one-half feet in height, — that is, there was an old mud sill there and this dam must be at least two and one-half feet above that old mud sill, — and we might store water for one year's supply of the city of Taunton, but we must maintain the natural flow of the stream.

There were some rather peculiar terms in the act. What the natural flow of the stream is it is hard to express; I suppose, in one sense that the natural flow is all the water that runs down that stream, but the Supreme Court has passed upon the act (166 Mass. 540) and said that it couldn't say just what the words meant, but that the intent was that we should let down during the dry season as much water as usually went down there, and we might store and use the water which came from thaws, freshets, and recent heavy rains.

The town of Middleboro owns part of the first water privilege below the lake, from which they get power to furnish electricity for the town of Middleboro. We took this water in July, 1894, and within a year they brought an action against us for diversion.

For eight years the suit was carried on the court records and no action taken by the town to bring the case to trial. In 1903 they began to move to get their money. The first action was heard by the county commissioners of Plymouth, and the city put in no defense, our attorney claiming that the town had not made out a case. The town put in its evidence and the county commissioners awarded $2 000 damages. From this award the city of Taunton appealed.

A year or two afterwards Marcus Morton, Esq., of Boston, was appointed auditor by the court, and heard the case.

There is a little peculiarity in the deed of the water power to the town of Middleboro. The town is entitled to the use of the first 75 horse-power in that stream. If there is anything above that, I suppose that it is entitled to what it can get from the stream, but more than half of the dam belongs to some one else. There are two or three other opportunities to draw water, so that the amount of water the town could get over the 75 horse-power to which it is entitled would probably be small.

The auditor found that Taunton does not damage Middleboro if it is entitled to only 75 horse-power. If it is entitled to what they claimed, 125 horse-power (which was the development of their wheels), and if Taunton could operate its dam adversely to the interests of Middleboro, he estimated the damage at $1 200; but if it was entitled to more thant 125 horse-power he could not determine the damage, as there was no evidence submitted.

From this decision of the auditor the town of Middleboro appealed.

Mr. Freeman C. Coffin had been the engineer for the city of Taunton, and for four years made gagings on that stream, one year before the dam was built and three years afterward. His gagings showed that more water went down stream during the dry months after the dam was built than before. After Mr. Coffin's death the city of Taunton employed Mr. Metcalf as its engineer. There was a trial before a jury in Brockton in November, 1907, and the jury awarded the town $12,000 damages. That, of course, includes interest, so the verdict would be about seven thousand dollars, and interest.

Judge King, of Springfield, presided, and he cut the verdict down

to $3 500, or he said that he would set the verdict aside unless the town of Middleboro would accept $3 500, which they refused to do. Within the last two weeks the case has again been tried and the jury awarded $13 241.50, about seventy-five hundred dollars and interest. A motion is being argued to-day to set that verdict aside. The case will undoubtedly go to the Supreme Court.

We take about two million gallons per day. That means 2.6 horse-power at this mill. When we first began we took about 1.5 horse-power. Mr. Coffin testified that the city of Taunton could take 10 000 000 gallons per day and still give the town of Middleboro during the dry months as much water as it had before we built the dam.

At the trial before the auditor, Mr. Allen, of Worcester, was the expert engineer for the town of Middleboro, and it then seemed to be the policy of the town to make out as large as possible the amount of water carried by the stream, and that we took all the water that they didn't get. At the last trial they changed their tactics and made the amount of flow of stream as small as possible.

Mr. Leonard Metcalf. Mr. King has set the facts admirably before you, but there is perhaps one other point to which I may call attention. I might say that of this $2\frac{1}{2}$ feet in depth in storage over the ponds, the present consumption would correspond to from three to six inches, depending upon what ponds were included in the storage. There is an obligation in the taking of water from certain of the ponds by New Bedford as to the erection of weirs between the ponds, which results in limiting the flow, or determining the direction of the flow, at certain seasons of the year.

Furthermore, it may be of interest to add that it was estimated that the available power at this privilege was about seventy-five horse-power. At the time of the diversion, as Mr. King has stated, the diversion was about one and a half horse-power, and at the present time it is about two and six-tenths horse-power. The real estate experts put on by the town of Middleboro testified that the value of the entire plant, including the entire physical plant and its business as a going concern, the wires, dynamos, machinery, and so on, was $70 000, and that it had cost, I think, $63 000 as matter of fact about eight months before. In spite of that fact, the jury awarded the sum which Mr. King has stated for a diver-

sion at that time of $1\frac{1}{2}$ horse-power out of 75. The \$63 000 included a gas plant also, — a mere trifle.

Of course it seems very unjust from the point of view of equity, because as actually operated they are undoubtedly getting much more power to-day from that privilege with the water which is let down from storage during the dry months than they did before the construction of the dam, but the plaintiff laid great stress on the fact that the control of that storage was within the hands of Taunton. Of course it would be impossible for Taunton to hold this water up indefinitely; it has got to come down some time, and from a practical point of view it does not seem probable that Taunton would hold it up during the dry season to let it down in the wet season and encourage litigation. Compensation in kind, or compensation in storage of water, does not seem to have worked in this case.

LEAD-COVERED CABLES A CAUSE OF ELECTROLYSIS UPON WATER AND GAS PIPES.

BY A. A. KNUDSON, ELECTRICAL ENGINEER, NEW YORK.

[*Read February 9, 1909.*]

The subject of electrolysis upon underground pipes is, without doubt, of more or less interest to all water-works men, and any new cause for it, or features not generally understood, will doubtless claim your attention. We are, therefore, taking up that phase of electrolysis of water pipes which is caused by bonded underground cables, and which of late years has become a very important feature.

The principal cause of this phase of electrolytic action is due to the so-called bonding of the lead sheaths of cables to the railway return. By railway return is meant either the rails of an electric railway or a special copper conductor leading direct to the negative bus bar in the power house. These conductors are usually called negatives.

Such connections are made solely for the purpose of protecting the lead covering of the cables from electrolysis. The reasons for such protection will be found ample when we consider that telephone cables are valuable property. Some of them carry as high as 500 pairs of conductors. The wires of these conductors are very small and are insulated from each other and from the lead sheath with only very thin, dry paper. The smallest puncture, therefore, of the lead covering will admit moisture, and when this occurs the cable is ruined for a considerable length each side of such puncture. As an example that such damage often entails great expense to telephone companies, I am reliably informed that recently in one city there was a loss of $12 000 of cable property in one year by electrolysis.

This bonding of cables to railway returns has the effect of converting the cable sheaths into a part of the return circuit

of the railway, and places them in the same relation as to electrolysis of pipes as the rails on the street, except to a far more dangerous degree, because the pipes are much closer to the cable conduits in the ground than they are to rails, — in many cases but a few inches apart, and in some cases resting directly against the conduit. Under such conditions, where both metals are in wet soil, a low difference of potential — say a few tenths of a volt — is often sufficient to carry current and cause damage to main or service pipe.

The question may reasonably be asked: Why do not the conduits which enclose these cables act as insulators, as is claimed by some, to prevent railway currents from flowing on and off the cables. We think it worth while at this point to look into the construction of some of these conduits, as they have a distinct bearing on the subject. There are over twenty different styles of ducts manufactured in this country and abroad. We shall consider, however, only a few, which are in general use.

One method of construction is the terra-cotta conduit. There are several styles. One is called the multiple duct, which is made in lengths of 3 feet by 10 inches square, with a partition in the center, so as to accommodate several cables in each space. Another form is called the terra-cotta separate duct system, in which each duct contains but one cable. The latter system is more generally used, and is familiar to most of you from seeing them on the streets during construction. They are furnished in pieces 18 inches to 2 feet long by 5 inches square. In the multiple conduit, the joints are made by wrapping with jute or burlap, saturated with hot asphalt. In the separate duct system the joints are usually made with a thin cement mortar. All of these ducts, whether large or small, are enclosed in a mass of concrete, the size of which depends on the number of ducts.

In another method of conduit construction, used largely by telephone companies, the ducts are made of thin sheet iron with an interior lining of cement ½-inch thick. Several of this class are used in New England cities. None of these forms of construction can be depended upon at all to act as insulators and to prevent railway current flowing to or from them.

Another class of conduit ducts are made of fiber, saturated

with a bituminous material. Two companies are manufacturing this duct, which is made in lengths of 5 and 7 feet, with diameters from 1 to 4 inches. This type is claimed to protect from electrolysis. One of these companies, however, it is known, has declined to guarantee such protection, on the ground of water collecting in the interior. It should be understood that it is a most difficult matter to insulate underground cables, even with the most improved conduits, so as to prevent current flowing

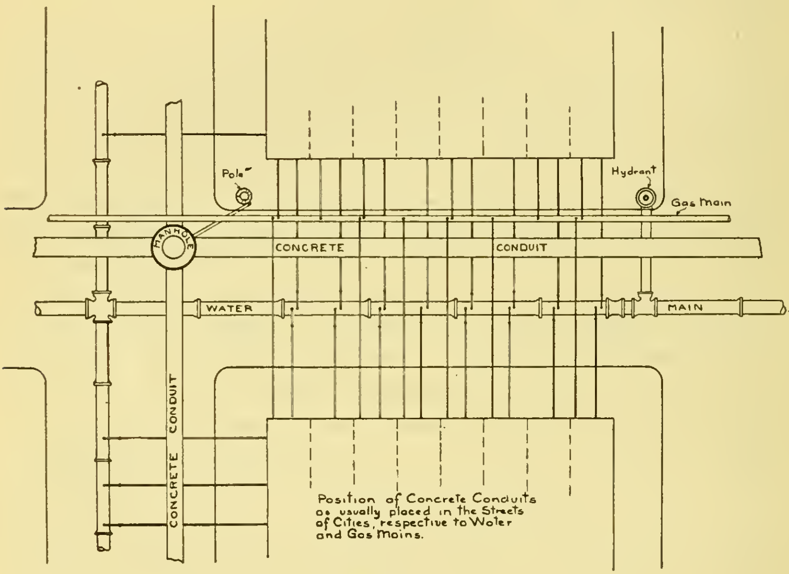


FIG 1.

from pipes into them, especially when they are near the points where the cables are bonded to the railway negatives. The method of bonding is usually made at the manholes, where each of the lead sheaths is soldered to the copper conductor leading to the power house. This practice of bonding has now become general in all cities large enough to support trolley and telephone companies.

As illustrating the flow of railway current upon underground properties, we call your attention to Fig. 1. This composite

drawing represents a typical condition which may be found in any city. The lead sheaths of the cables in the concrete conduit being bonded to railway negatives, the natural attraction for current flowing upon water or gas mains is directly to the conduit, either from the gas service pipes, which as shown usually cross directly over the conduit on their way into buildings, or water

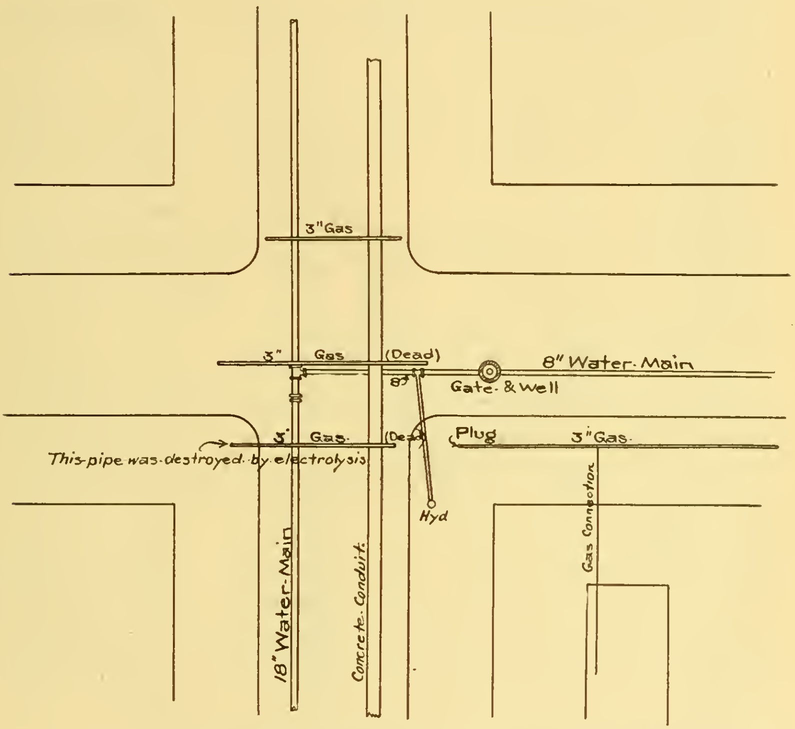


FIG. 2. SKETCH SHOWING POSITION OF 3-INCH GAS MAIN OVER CONCRETE TELEPHONE CONDUIT. THE MAIN WAS DESTROYED BY ELECTROLYSIS.

service pipes, which pass under them. This is the case also with hydrant branches, and pipes that pass into side streets, illustrated in the drawing. In other words, the conduit threads its way between the gas and water services as they pass into buildings along a street. One peculiarity in such cases is that corrosion

is not always confined to one spot under or over the conduit, but spreads several feet each side of it. In one city where we investigated, the water superintendent said he could not understand the cause of a number of his service pipes bursting along a certain street for about two blocks. He knew it was electrolysis, but the voltmeter tests between hydrants and rails did not indicate that such damage was going on. Suspecting the cause, we made a test between the telephone cables in a manhole and a hydrant, which at once showed the reason. The mains were positive to cables from 1 to 3 volts — the soil, wet clay and gravel. It often happens that pipes are damaged upon streets where there are no tracks. As a matter of fact, the tracks have nothing to do with this feature of electrolysis. We have known more than one case where water and gas superintendents have complained to the railway people that their pipes were being damaged by currents upon certain streets, and they would be met by the statement that it could not be railway currents because there were no tracks on such streets.

Fig. 2 illustrates how a 3-inch cast-iron gas main was destroyed for about thirty feet in a western city. This main passed directly over the concrete conduit, nearly or quite touching it. The ends of the pipe after the damaged part had been removed were plugged, and gas fed from each side of the conduit. The portion damaged was full of holes and pittings. The gas main was positive to the conduit cables from 1.0 to 1.3 volt — soil, wet clay. There were no tracks on this street, and the railway company refused to pay the bills for damaged pipe until we made the tests and the true reason for the damage discovered and explained. In this case the wet clay soil and nearness of pipe to conduit made up for the comparatively low potential of 1 volt to destroy the pipe.

Fig. 3. The plan and section is shown of a 3-duct conduit as found at an excavation recently in an eastern city; also cross-section drawing of a 20-inch water main, which crossed under the conduit at right angles. The main was 18 inches below the conduit. This main was positive to cables in the conduit to a maximum of 11 volts. Fortunately for the main, the soil was sandy. There was some corrosion, but not impor-

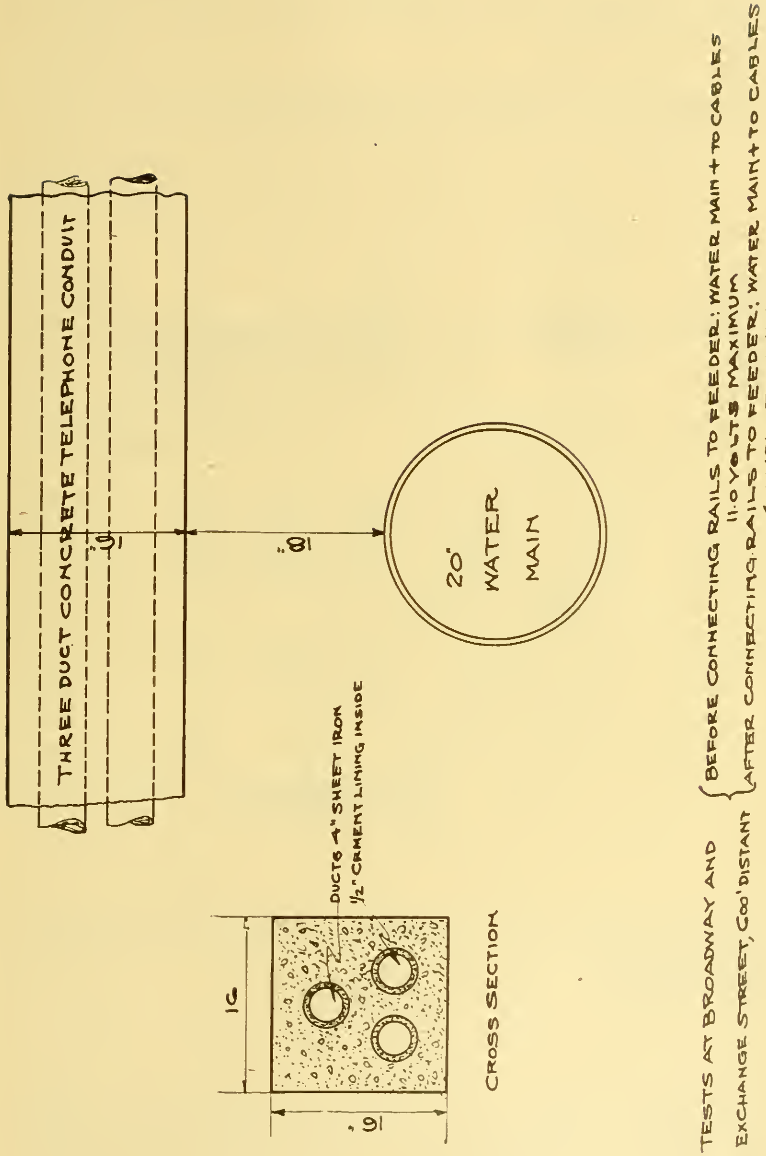
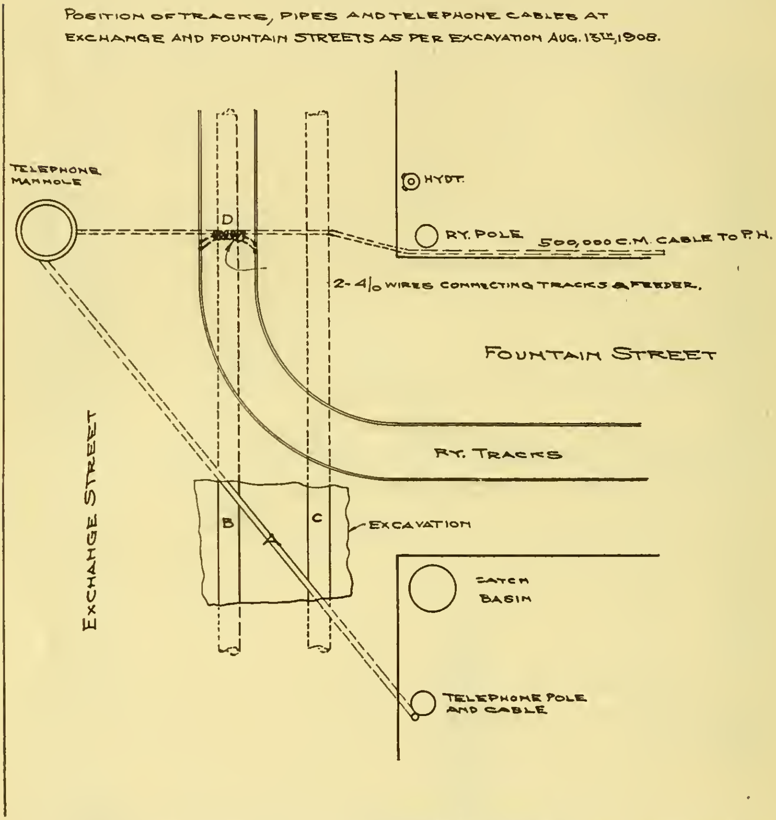

THREE DUCT CONCRETE TELEPHONE CONDUIT
10"
18"
20" WATER MAIN
DUCTS 4" SHEET IRON
1/2" CEMENT LINING INSIDE
16
16"
CROSS SECTION
TESTS AT BROADWAY AND
EXCHANGE STREET, 600' DISTANT
BEFORE CONNECTING RAILS TO FEEDER; WATER MAIN + TO CABLES
11.0 VOLTS MAXIMUM
AFTER CONNECTING RAILS TO FEEDER; WATER MAIN + TO CABLES
4.0 VOLTS MAXIMUM

Fig 3.

tant, as it was spread over the surface, and no pittings. The ducts in this conduit were of the thin sheet-iron class, with the interior cement lining.



A UNDERGROUND IRON PIPE WITH LEAD COVERED CABLE INSIDE WHICH GOES UP POLE. RESTS ON B.
B 6" GAS MAIN
C 6" WATER MAIN
D POINT WHERE RAILS AND FEEDER WERE CONNECTED

FIG. 4.

Fig. 4. This was located a short distance from Fig. 3 in the same city, and will be of interest as showing the effect of a bond connection from the cables to the power house. The maximum

potential between water main and telephone cables was also 11 volts at this point. The rails were 10 volts positive to the cables. The rails were, therefore, being robbed of current as well as the pipes by this connection. The gas main was also of the same potential difference to cables as the water main. The iron pipe *A* contained a lead-covered cable which crossed the street diagonally to a distributing pole and rested on top of the gas pipe *B*, which was found very badly corroded. The copper conductor shown in the drawing from the manhole to the power house a short distance away is of 500 000 C. M. capacity. The effect of this heavy connection was the cause of the high potential readings between pipes and cables over a large area. It was really a case of "over-bonding." The railway company coöperated with us in the attempt to remedy this dangerous condition, and to that end a connection was made at *D* between the copper conductor and the rails under which the conductor lay as it passed to the telephone manhole. This connection had quite a pronounced effect in reducing the high potential difference between mains and cables. After the connection was made, the highest observed reading at this point was 4 volts instead of 11, and at other points where equally high readings had been observed, they were reduced to 2.2 volts maximum readings. Between tracks and cables, instead of 10 volts, the polarity, varying slightly in both directions, could be measured only in millivolts. Between mains and rails the readings were slightly higher with mains continually positive, where formerly the polarity was in both directions.

On the whole, however, the connection to the rails relieved a menacing situation, and in view of the sandy soil but little is now to be feared from electrolysis, unless a service pipe or main somewhere is close to or in direct contact with the conduit. This bond to the telephone cables (before it was changed) placed the mains dangerously positive to the cables for over a mile in one street. No attempt was made apparently to ascertain what effect such bond had upon the mains by either the telephone company or railway company, and the water department, of course, was in ignorance of such bond, which was causing corrosion upon the mains which would doubtless have been very serious if it had been left undisturbed.

Fig. 5. Shows a resistance curve of a block of concrete when submerged in water. This view was shown in our paper before the Institute of Electrical Engineers in New York, and illustrates the rapid fall of resistance of concrete when submerged in water or placed in damp earth. It will be noticed that, owing to its moisture absorbent qualities, concrete breaks down as an insulator in about seventy-two hours, becoming a fairly good conductor, — even better than the average soils found in the streets of cities.

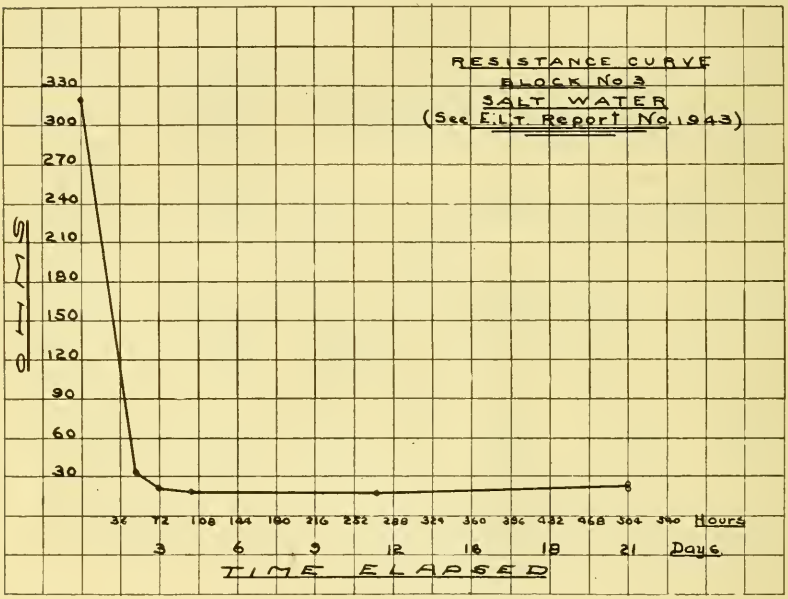


Fig. 5.

This is pertinent to our subject, as we are dealing with a long stretch of concrete in the ground much too close to pipes for the comfort of their owners.

At the topical discussion of this Association in December, 1905, Mr. W. E. Foss described a 6-inch main destroyed under a telephone conduit as follows:

"A 6-inch hydrant pipe burst while the hydrant was in use during the fire which destroyed the Academy of Music in

Chelsea, Mass., January 11, 1905. This break was due to the disintegration of the iron by electrolysis at the point where it crossed under a telephone cable, which had been bonded to the railway return for protection."

Fig. 6 refers to an intersection of streets in a large city showing water mains, telephone, and electric light conduits, illustrating

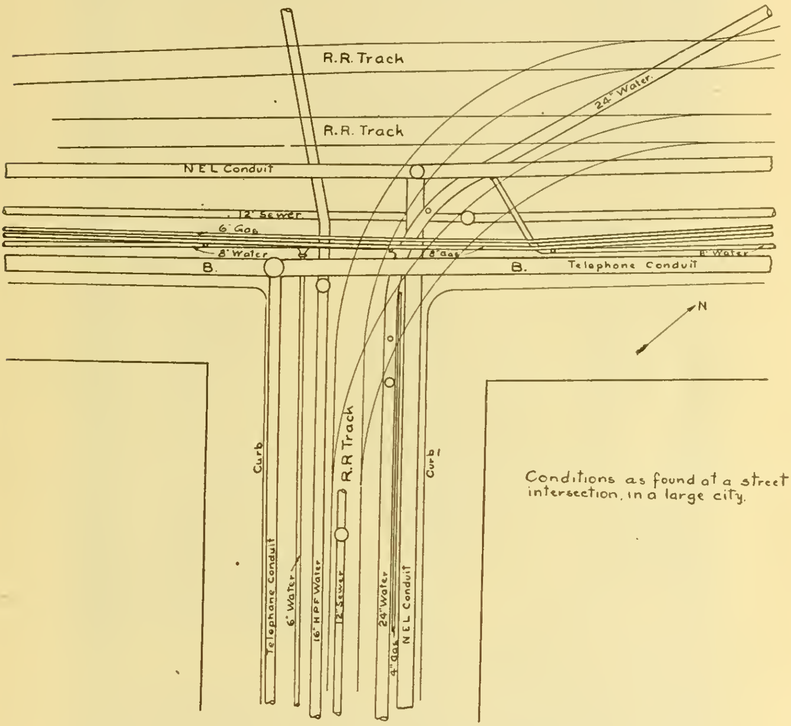


FIG. 6.

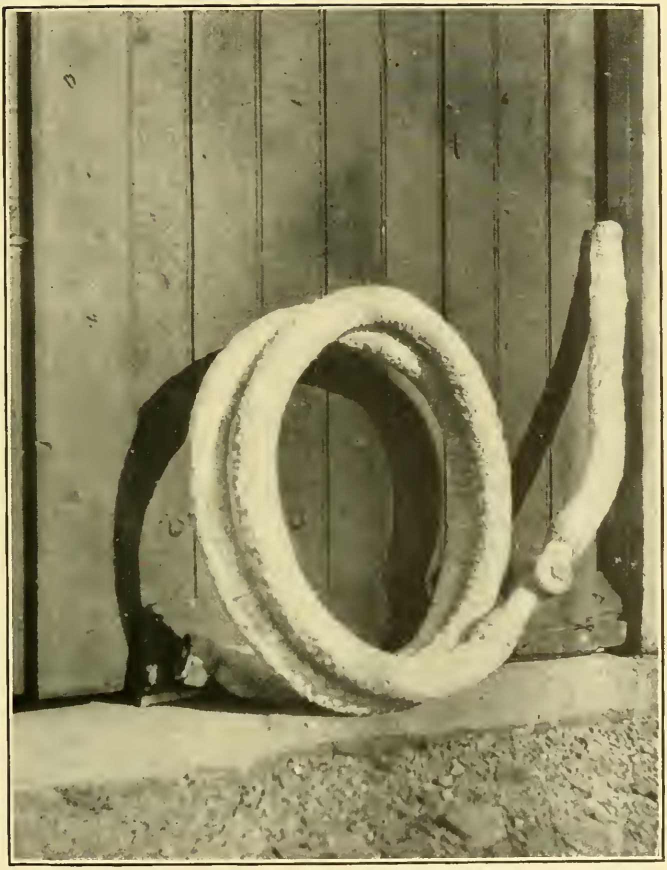
another case of "over-bonding." Two copper railway conductors of 500 000 C. M. were found connected with a through line of telephone cables in this conduit in one of the principal streets of a large city. These connections were only about 500 feet apart. Tests made by the writer in 1906 disclosed a dangerous condition for the water pipes. Mains were positive to the cables

2.5 volts, and two service pipes had failed which passed under the concrete conduit.

Plate I is from a photograph of one of these lead service pipes which failed. This pipe was damaged from the main to the building, some twenty-eight feet, so badly it was considered unfit for further use and was replaced with new pipe.

Referring again to Fig. 6, the attention of both the railway and the telephone companies' engineers was called to this continuing menace to pipes, but nothing in the way of remedy at that time (1906) was undertaken. Last fall we made this case a special study, as three more services had failed, and the mains were being damaged. An effort at remedy was undertaken with both companies coöperating. It was believed that two such large conductors so near together were unnecessary for cable protection and that one or possibly both could be dispensed with. One of these conductors was, therefore, cut, and a large switch inserted, so that tests could be made with the conductor open and closed. All the telephone people asked was that their cable sheaths be kept negative to rails, and we did not propose to deprive them of protection. It was found, however, when the switch was open, that the cables were still negative to rails 0.2 to 1.3 volt. With the switch closed during the evening peak load, the potential difference reached 10 volts negative to both pipes and rails. In other words, under normal conditions the water mains during the day load were 2.5 volts positive to the cables and at evening load 10 volts. The other cable connection was also opened, and it was found, with some surprise, that the telephone cables still remained negative to rails, so that with both conductors disconnected from the cables they were protected and in no danger from electrolysis. Both of these connections were, therefore, permanently dispensed with. With both conductors open, the water pipes were 0.4 volts positive to cables. The heavy flow of current on these conductors when connected to cables was measured. On one of them there was at times of peak loads 750 amperes, and on the other, 350 amperes, or a total of 1 100 amperes, all of which *had* to flow through a portion, at least, of the lead coverings of these cables.

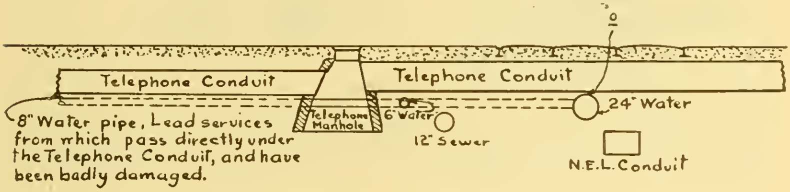
The drawing Fig. 6 shows where this telephone conduit was



placed, and the water pipes which pass under it. There are three water mains which cross at right angles, — a 24-inch, 16-inch H. P. F., and an 8-inch. Parallel with the conduit is an 8-inch close under the conduit, which passes through two telephone vaults, they being built up around it. It was in these vaults that the connections were made.

Fig. 7 is a cross section of the 24-inch main, showing the conduit 10 inches above it; also plan view of the telephone conduit with the 8-inch main passing through one of the manholes. This main was uncovered at this point, and considerable corrosion found distributed over its surface, but there were no pittings, so far as could be seen.

The part underneath the conduit showed a heavy deposit of



Section taken on B-B, in line of Telephone Conduit, Looking N.W.

FIG. 7.

oxide of iron about an inch thick in the sandy soil. An interesting sample of the scale from this main, which includes a stone, is furnished as an exhibit. This scale, which is simply sand filled with the iron deposit, is the best evidence of electrolytic action upon a water or gas main.

Fig. 8 shows a view of a conduit in another street in the same city, where it was found resting directly upon an 8-inch water main. Pittings were found on the main each side of the conduit.

Fig. 9 shows a main in the same street as the former, a few blocks south. It was 11 inches below the conduit, which gave an opportunity to examine its condition. Several pittings were found, some quite large and $\frac{1}{8}$ inch in depth. In these two cases the potential difference was 1.8 volts maximum, the direct test

between the conduit side with a wire nail driven into it for connection and water main was 0.5 volt, and the same with an 1½-inch gas pipe, which was nearly destroyed at that point.

In view of the importance the bonded cables have in respect to

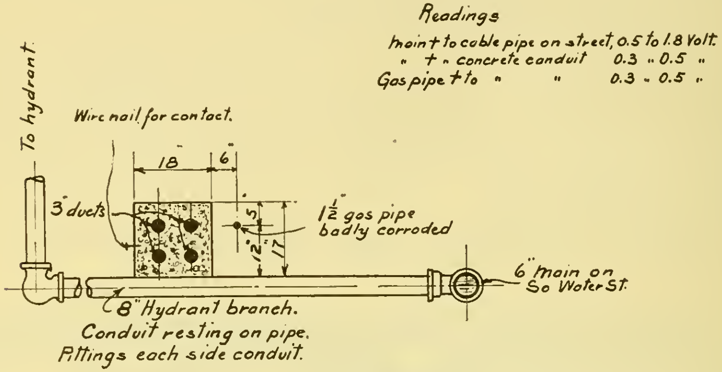


FIG. 8. EXCAVATION AT SOUTH WATER AND SILVER STREETS, PROVIDENCE, R. I., NOV. 23, 1908, SHOWING POSITIONS OF TELEPHONE CONDUIT AND WATER MAIN.

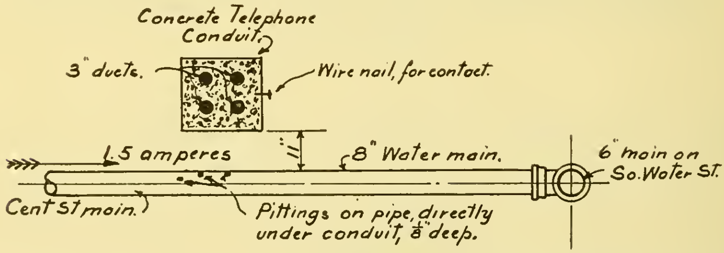


FIG 9. EXCAVATION AT SOUTH WATER AND CENTRE STREETS, PROVIDENCE, R. I., NOV. 23, 1908, SHOWING CONDITION AS TO CONDUIT AND MAIN.

electrolysis upon pipes, the telephone companies should be required to furnish to water departments a plan showing where their cables are connected to the railway return as well as the size of such connections, and also to report any additions or changes in these connections.

Those in charge of water works should have their own voltmeter, so that tests can be made between *cables* and *mains* and a watch kept of the potential differences. In most cases a voltmeter connection can be made between hydrants and cables by pressing a file against the iron pipe which encloses a lead-covered cable, where it passes up a telephone pole to the distribution box. In such case it is not necessary to remove the heavy manhole covers; besides, such covers should not be removed without obtaining permission from the telephone company. No regular survey for electrolysis in a city nowadays should be considered complete unless it includes thorough tests between underground cables and mains, as well as between rails and mains. The cable tests are, we believe, of greater importance.

The two cases of "over-bonding" we have mentioned may have been due either to a mistake in engineering or to changes in railway return feeders after such bonds were made. As a result of these discoveries the railway company and the telephone company are required by both of these cities to report to the water departments any future connections that are to be made. The telephone company should be required to show, by temporary connections and tests, what the potential difference is to be between pipes and cables before they are made final. The bonding of cable sheaths to railway returns should be made with the city considered as a whole, and not indiscriminately, such as placing bonds mostly in one place. No concrete conduit should be allowed on top of or resting against a main anywhere in a city. Such a condition is practically the same as though the pipes were bonded to the railway return.

No consideration by either telephone companies or railway companies seems to be given as to the effect cable bonding has upon adjacent water and gas pipes. Pipes in the ground need protection from electrolysis just as much as telephone cables, and the protection of cables should not be at the expense of the pipes. This phase of electrolysis, therefore, as we have endeavored to show by practical illustrations, introduces new features and problems which are often difficult to solve when looking for remedy. Acute cases may sometimes be modified similar to those mentioned, but, after all, in looking for the prime

cause of this phase of electrolysis upon underground pipes, we are brought back to the same old cause prevailing in many other directions, namely, the grounded circuit of the electric railways.

DISCUSSION.

Mr. Bowers. I would like to ask Mr. Knudson how near it is possible with safety to lay a conduit to a water-pipe. In the illustration that he showed us they were 11 inches apart, and the pipe was in bad shape. I would like to know how near they can be put together safely.

Mr. Knudson. It is just as well to keep the pipes as far away from the telephone conduits as you possibly can. Where the service pipes go underneath the conduit to buildings, instead of putting them up against the bottom of the conduit, let them go down as deep as possible. Keep them as far away as possible, because there is no telling how the current will flow along the pipes and pass out of them at any convenient point, and generally the point which is nearest to the conduit is where the most of the current leaves. I don't know that any prescribed rule can be laid down as to the distance, whether 6 inches or 12 inches or 2 feet. It depends largely on the character of the soil as well as on other things. If the soil is of sand there will not much current pass, even at 11 or 12 inches; if it is wet clay, then you may expect the current to pass in such cases. It depends largely on the character of the soil. I do not see how we can place the distance for safety as a rule between conduits and pipes that will apply in all cases.

A Member. I understand that the damage is done to a water pipe where the electrical current leaves and not where it enters it. Now I would like to ask if there is any way of knowing when a pipe has become charged, so that a person, say a workman, when he is digging up the pipe, could tell or have reason to suspect there is electrolytic action taking place there, before the pipe has got so bad that it will show pitting, — from the softening of the metal, or something of that kind.

Mr. Knudson. Such cases have occurred where workmen are quite familiar with electrolysis effects. If they find that there

are pits, which can be dug out of the pipe, then they know, you might say by rule of thumb, that electrolytic action is going on. But the ordinary workman very rarely discovers such pittings. They have to be looked after and examined for. If the surface of a pipe that is damaged is cleaned off it will look about the same as an almost new pipe to the casual observer. But if you take a hand pick and go around and sound on that pipe, you will be very apt to discover pittings here and there if corrosion is going on. An ordinary workman, perhaps, or the foreman of the gang, can then find these places by sounding or tapping around on the pipe with an ordinary short, sharp hand pick. A test should be made with a voltmeter so as to verify it, to see what voltage there is between the pipe and the rails, and you will, as a rule, find these pittings when near the rails; not in the outlying sections of a city where the current is going *into* the rails, but where it is coming *out* probably not far from the power house.

Mr. McMillen.* I would like to ask if it is true that the pipe becomes soft, after it has been charged, before it shows any sign. As I understand it, the metal will become soft. Now, of course, a man drilling a hole, say, making a tap, if he found the pipe soft when drilling, would have a pretty good indication that he should look out for electrolysis. What I mean by that is that a common workmen might have reason to suspect that there was electrolysis without the use of any special appliances.

Mr. Knudson. That might be the case if in drilling a pipe he came across a portion of the pipe which was soft. That would mean that you ought at once to have tests made to see if there were electrical conditions which would cause electrolysis at that point.

* Superintendent of water works, North Billerica, Mass.

GROUNDING ELECTRIC LIGHT WIRES ON WATER PIPES.

BY F. E. MERRILL, WATER COMMISSIONER, SOMERVILLE, MASS.

[*Read February 9, 1909.*]

Although the study of electricity and its effects is, in the main, foreign to the requirements of a superintendent of water works, yet in some ways, as with the subject of the electrolytic action on water pipes of currents from underground sources, and that of the grounding on water pipes of stray currents from overhead sources, the water-works superintendent is brought more or less closely into touch with matters pertaining to the action of that force, through its connection with other public utilities and through the studies which become necessary for him to make in order to deal intelligently with the problems which arise in connection with his own works on account of such relationship.

The subject of this paper, then, is not to be treated by the writer from a technical standpoint, but is presented as an "experience paper," giving, for the information of other superintendents who may be considering the matter, a brief review of the study made of the question of grounding electric light wires on the water pipes in the city of Somerville, and its results.

The matter of grounding such wires on the distribution pipes of the Somerville water works was first brought before the writer for his consideration some seven years ago, when a formal request was received from the general manager of our local lighting company for permission to attach the secondary connections of the company's transformers to the mains of our water distribution system.

The reason given for such request was that the safety of their customers and of the public made it necessary that the secondaries be grounded, and that, while it was their intention in most cases to make the ground at the base of the pole by digging down to damp earth and placing there a copper or other metallic plate, or by driving an iron pipe down to water, there were some places where

the nature of the soil would make this method of grounding impracticable, and in such places they wished to make direct connection with the water mains. This connection they proposed to make in a manner approved by the water commissioner, and they agreed to give any reasonable guarantee to protect the city in every way from damages caused by such attachments. The method at that time suggested for connecting the wires to the mains was by means of a plug screwed into a hole tapped in the pipe as near as practicable to the transformer. Permission to ground their wires to the water pipes within buildings was not at that time sought. Support in their contention for the desired privilege was given by the National Board of Fire Underwriters, who had made a provision in their printed rules and regulations that such wires should be connected to all available underground water pipes, anticipating, presumably, no opposition on the part of the owners of water works to such use being made of their property.

While the arguments advanced by the lighting company, in support of their petition, seemed sound, and the menace to the property and interests of the city appeared to be remote, nevertheless an electrician to whom the matter had been submitted advised that, on account of the uncertainties of the effect of electric currents which might get into the water pipe system, and the difficulty, if any trouble did arise, of establishing the fact that it was caused by ground wires, and the possibility of attendant complications, it would be better not to grant the desired permission. So it was decided at that time not to allow the use of the water pipes for any other purpose than the conveyance of water, as the lighting company had not established the fact that their stray high-tension currents could not be disposed of through some other medium than the water distribution system.

Some years later another lighting company, which had in the meantime absorbed the property of our local company, made an attempt to ground its house service wires on the water pipes entering the premises without first having obtained authority from the city to make such use of its pipes. To this procedure the city naturally objected, and its subsequent action in the matter led the lighting company to discontinue its work and to commence nego-

tiations for obtaining the desired privilege. This resulted in another consideration of the whole subject on the part of the city, and a deeper investigation into its merits and its objectionable features.

The lighting company set forth in its argument in favor of the grounding privilege that within the last few years there had been a considerable number of accidents due to the high-tension current getting on to the house wires which were intended to carry low-tension currents only, — in some cases caused by actual contact between the wires on pole lines and in other cases due to the breaking down of transformers; that there was absolutely no current passing over the wire under normal conditions, but that in the event of a breakdown in the transformer, or the crossing of wires in the street, the current would flow for an instant of time over the secondary, blow the fuse in the transformer, thus disconnecting the electric supply to the premises, and, supposedly, escape via the ground wire to the earth through the water pipe, thus protecting the house and its occupants from injury; also that it was practically impossible to obtain a proper ground in places situated on elevated land by driving pipes in the street, and that the only other way to accomplish the purpose was to connect to the water pipes.

The statement of their case thus advanced by the lighting company seemed to indicate a necessity for the adoption of some protective measure to avert danger to life and property, and while it did not appear clear to the writer that danger would be averted to the workman who happened to be setting a water meter or repairing a service pipe at the time that a stray high-tension current came along such a pipe; or that the method advocated by the company, of attaching their wires to the water pipes, was the *only* one available to them of accomplishing the desired result, inasmuch as a copper plate buried in the earth in an approved manner and properly connected would make a most excellent ground for the lighting service of each house, yet grounding on the pipes did seem to be the easiest and least expensive method, and so, with the desire to coöperate in the matter as far as it appeared to be practicable, the city pursued its investigations further, calling in a consulting electrical engineer and expert for his opinion and advice on the following points, viz., As to the

danger, resulting from attaching ground wires to water pipes, of injuring workmen engaged in setting meters or making repairs on the pipes, or other persons, or the general public, or property; as to the possible injury of the water pipes; and as to the general propriety of such an arrangement.

In his report this expert stated that he regarded the grounding of the secondary wires a necessary safety precaution, the neglect of which almost amounts to criminal negligence, and that the only question involved was the way in which this grounding should be carried out. From the opinion of this expert it was gathered that (using in part his own language) although a ground wire, when the system is in its normal condition, carries no current of any kind, it *may* carry more or less of the secondary, low-voltage current owing to accidental grounds elsewhere; or it may receive the primary current through a fault in the transformer, for a high-tension primary system is now and then liable to accidents, and it is the office of the ground wire to avert danger in such cases. If properly installed there is no probability of a shock from the secondary current, and there would be no danger from such a shock at the ordinary secondary voltages even if it did occur, although it might be a bit surprising. When the primary current, on rare occasions, does break through the transformer insulation, the ground wire thus charged, if securely grounded, is not a source of danger, and, in fact, averts very grave danger; the transformer under these conditions is burned out and the fault becomes apparent. When practicable it is better to ground outside a building than in it, but in many cases it is difficult to secure a good and reliable ground in this way, and it becomes advisable to carry the ground wire through the cellar wall to ground at the nearest practicable point on the water piping. If proper precautions are taken, this is entirely safe. Injury to the water pipes from grounding upon them is a remote contingency. The chief possibility of danger to be guarded against is while repairing a house water pipe; this can be overcome by disconnecting the transformer temporarily or by other means, such as detaching or cutting away the connection on the house service pipe. "In my judgment," the expert reports, "the chances of trouble while working on water services upon which secondaries are grounded are very remote, but they

exist and can be practically avoided. No injury to the water pipes is to be anticipated as the result of grounding, but in using the water pipes for grounding the illuminating company should co-operate with the water commissioner to the fullest extent by seeing that the work is well performed and properly maintained."

After thoroughly studying this expert opinion it seemed tha the city might with safety and propriety permit the use of its water pipe system for the purpose desired by the lighting company if a satisfactory working agreement could be made; so the next procedure on the part of the city was to attempt to draw up a form of agreement which would be mutually acceptable to the city and to the company. Spoken quickly this seems an easy matter, but in this case it took the greater part of a year before the reconciliation of conflicting opinions could be effected and the necessary signatures attached to the instrument.

The agreement as finally assented to and signed by the lighting company provides that, whereas said company desires to ground its secondary wires which run from poles and underground conduits to buildings in Somerville on distributing pipes which are connected with the water system of said city, the purpose of said grounding being to provide greater protection against injury to persons and property from electricity passing along said wires, permission is given for such grounding, subject to certain conditions, viz.:

Such grounding shall be done and maintained in a manner satisfactory to the water commissioner and the commissioner of electric lines and lights of the city.

The water commissioner may at any time remove any or all such wires and the company shall pay to the city the expense of such removal.

Such permission may be withdrawn and revoked by the water commissioner at any time as to all or any of said wires, and thereupon the company shall forthwith remove the same, and its rights to make or continue such grounding shall forthwith cease and terminate.

That, as all secondaries should be grounded as a precaution for public safety, the lighting company must see to it that this is done as quickly as possible.

That when this grounding is done within a building the work is to fully comply with the insurance regulations, with particular attention to making the ground connection with the water pipes as near the cellar wall as possible, and not further in where it will be in the way of working on the pipes and water meters.

That whenever it is, in the judgment of the water commissioner, practicable to make a suitable ground outside the building or at certain points on the mains themselves, this is to be done, and that such grounds are to be made by plugs screwed into the pipe, and not by clamps, and that they must be rigorously inspected and kept in order by the lighting company.

That in order to avert possible danger in working upon water services on which grounds are made, the lighting company, whenever notified to do so, is to disconnect its wires during the course of repairs and reconnect them when the work is completed.

That in case of temporary repairs, when such notification cannot be waited for, the water department is authorized to clear the ground wire by removing the clamps or by cutting the wire in order to proceed with the work, but they must at once notify the lighting company to reconnect; it being understood that the lighting company shall hold the city harmless in any casualty resulting from lack of such notification, and shall make suitable inspection to maintain its grounds intact throughout the city.

The fifth section provides for the payment of an agreed sum to cover the estimated cost to the city for clerical work, inspection, and other expenses incidental to the subject-matter of the agreement.

Section 6 provides that this agreement shall apply to all such connections with the water system, whether heretofore or hereafter made, and whether made by the company or by any other corporation or person, it being the intention that the company shall assume entire control of such connections and all responsibility therefor.

Section 7 provides that the company shall furnish the water commissioner at all times a full and correct statement, in form satisfactory to him, of all buildings and places where wires are so grounded and shall keep such statement accurately revised.

And finally, the lighting company accepts the permission on the

conditions herein stated and agrees with the city of Somerville that it will indemnify and save harmless said city from losses, liabilities, damages, claims, and suits arising in any way out of said grounding of wires or out of said permission.

As it was now felt that the interests of the city of Somerville were satisfactorily protected in the matter, it became the pleasure of the water commissioner to authorize the lighting company to proceed with the grounding of their secondary wires on the water pipes of the city, and at the present time seven hundred and eighty are so connected and no deleterious effects or difficulties of any kind have come to the writer's knowledge as a result of such grounding.

Now, Mr. President, before taking my seat, I wish informally to introduce to you, and the gentlemen present, several officers of the Boston Edison Electric Illuminating Company, who have kindly consented to come here this afternoon as my guests, and to take such part in the discussion of the papers as may seem to them desirable and advisable from the standpoint of the lighting company. Mr. Cowles, superintendent of installation of the Edison Company, under whose direct supervision I understand the installation of house services comes, has kindly expressed his willingness to answer any questions which any members may like to ask relative to the grounding of transformers or house service wires and the precautions and methods which the Edison Company has taken to protect life and property from currents passing over wires. Mr. Lott, whom many of us know as the former Commissioner of Wires of the city of Boston, now the Superintendent of Right of Way and Street Lighting of the Edison Company, on account of his long and varied experience with city officials in the matter of making agreements, etc., I am sure can say something of interest to us. Mr. Smith was the one who, as superintendent of our local lighting company, first brought to my attention the grounding of secondary wires of transformers to water mains. He is now an official of the Edison Company. For some time previous to his service as superintendent of the Lighting Company in Somerville he was superintendent of water-works in a western city, and, therefore, he is, I am sure, additionally welcomed to sit with us this afternoon, on account of his former membership in

the water-works fraternity; and I think he can speak to us with interest from his double standpoint of water-works and electric light superintendent.

DISCUSSION.

The President. Gentlemen, you have heard Mr. Merrill's paper, and what he has had to say about the officials of the Boston Edison Electric Illuminating Company being here. Of course this is a subject which will bear a great deal of discussion, and especially in connection with Mr. Knudson's paper, for I presume that what applies to grounding electric light wires also, to a certain extent, applies to grounding telephone wires; that is, if the telephone wires came in contact with the electric light wires you would have the same potential on your pipe in one case as in the other. I hope the members will be free to discuss the subject and to ask any questions they want, and I can assure the gentlemen from the Boston Edison Company that we will be very glad to hear from them and to get any information possible.

Mr. John C. Whitney.* I should like to ask Mr. Merrill, in case of the death of an employee of the Somerville Water Department, caused by a stray current on this connection, to whom would the heirs of the man look for damages?

Mr. Merrill. Fortunately, Mr. President, we haven't had any such case, but I presume they would look to the city, in the first place, and the city naturally would look to the lighting company.

Mr. Knudson.† I don't know who the expert was who made that report to Mr. Merrill, but it seemed to me to be a very good one indeed. I have made reports on the same line in another city; in fact, in two other cities, and the report which was made to Mr. Merrill coincided very closely to the two that I made, possibly with one exception, and that was in regard to grounding in the outlying sections, where there is an alternating current. In this city which I have reference to there was, some years ago, a burn-out on a transformer which was on a pole. That

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* Water Commissioner, Newton, Mass.

† Electrical Engineer, New York City.

threw the high-tension current into the lamp circuit and into buildings and houses. There were two fatalities. Now, we didn't want to order out the grounds on those pipes, and we didn't; we let them stay there, but thereafter in our recommendations we suggested that wherever it was practicable the ground in the outlying sections, where the alternating current prevailed, should be made to the mains in the streets and not inside of buildings.

We made another point, too, in regard to connecting the grounds inside of buildings to water-pipes. Suppose, for instance, an accident happened, — the transformer was burned out at the time the men were at work on the outside of a house repairing a service pipe and a high-tension current went through that part of the circuit; if the service pipe was separated just at that time and a man had hold of each end of the pipe, there would be an opportunity for a fatal accident. In such a case would the city be responsible for giving permission to make this ground? That was a point discussed in our report and provided for.

Mr. William E. Foss.* I would like to ask Mr. Merrill why it is ever necessary to make the ground inside of the house rather than to the main outside of the house.

Mr. Merrill. As matter of convenience in inspection, I should say, and as a saving of expense. The provision was that if at any time it seemed expedient to ground the wires outside of the houses, that should be done. I presume your thought, Mr. Foss, is to ground them on the water mains at the transformers?

Mr. Foss. Yes, I think it would be much preferable to grounding them inside the house, for I have found very high resistance joints in the service pipes, especially at the meters, 1,000 ohms sometimes. A ground on the house side of the meter would be of no use whatever as a safety valve, and the place for it, I should think, is outside on the mains.

Mr. Merrill. That is undoubtedly so under those conditions, but the requirement is that the ground be made not on the house side but on the street side of the meter, beyond the shut-off and meter joints, so it has not been thought needful to require the company to go outside the wall with their wire and to adopt the

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* Division Engineer, Metropolitan Water Works, Boston, Mass.

expensive measures that would be necessary in order that such grounds might be inspected and properly maintained.

Mr. Foss. Are any tests made of the resistance of the joints in the service pipes back to the main before grounding is allowed?

Mr. Merrill. If so, that comes under the supervision of the department of inspection of wires. The commissioner of wires might tell you, but I am unable to answer the question as to just what tests are made. The water department has not made any such tests.

Mr. Foss. Then there is the possibility of lightning striking on the transformer circuit and getting into a house that way, which would not occur if the transformer was grounded on the main.

Mr. Merrill. I would suggest that at this time, perhaps, as Mr. Lott is a great deal more of an electrical expert than I am, and Mr. Foss's reputation in that direction is well-known to everybody, it might be well now to hear from Mr. Lott in regard to the matter of grounding. Perhaps he can give us some information which will be of interest.

Mr. Doyle.* I would like to ask why it is necessary to ground either telephone or electric light wires to service pipes either inside or outside? We have in Worcester over 16 000 services, and I don't know of one that is a ground either inside or outside.

The President. We will hear what Mr. Lott has to say, and I understand that later Mr. Cowles will answer Mr. Doyle's question and any other questions which may be asked.

Mr. William H. Lott. Mr. President and Gentlemen, I have heard one of the fairest and squarest reports, on a subject that a man might well be a partisan on, that I have ever had the pleasure of listening to in my life.

Now when this matter came up, it was in this manner: It was a new proposition. It seemed the solution of something that had been for years on the minds of everybody interested in the situation. It developed that this thing could be done without harm to the water-pipes. The technicalities of this matter I am not going into. Mr. Cowles is the man to do that, and what he doesn't know about this matter won't be worth talking about,

* General Foreman, Water Dept., Worcester, Mass.

so when I get through you can ask him anything you are a mind to and he will answer your questions. I simply want to state in a plain, practical way the facts concerning the situation in Somerville.

When we started we went on the theory, and I believe the theory is still good, that permission from the householder, the man who owned the pipe, was sufficient for all our needs. So in every case we received a permit from the householder to make this attachment, after explaining to him the necessity therefor, and explaining matters so as to relieve his mind as to any possible trouble. We went along, and I don't recall that we had run up against a snag in a place, excepting in one town adjoining Somerville, and I put the matter to them in this way, just as I did to everybody else: Where does the water company come in? That is the first point to be established. Have they been able to show any damage, any injury, or anything of that nature? Not yet. Now I said, gentlemen, this is a matter where it is sufficient for us if we have permission from the owner of the house to make this attachment. It is conceded by all interested parties that it should be done. Now, if you come into this thing, which I don't think you ought to do, then you become a party to it, and my advice to you is, until the thing is further developed and more information obtained about it, take the wisest course and have nothing to do with it. And I have this to say, that in every city and town on the Edison system, with the exception of one city and one town, they have thought that was the thing to do, and have no doubt that they are waiting to-day watching developments; and as soon as the water companies can show damage, incidental or otherwise, then they will have a right to come in, but until then I question very much whether they have or not. However, that is only my opinion. In the case to which I have referred, I said, "Now, gentlemen, if you want to become a party to this and come into it, then we will give you a guarantee or an indemnity bond that will save you harmless from all damage." The town accepted that, and we are satisfied, and we have never had a word of complaint from that day to this, and that was four years ago.

But in Somerville we found it quite different. Corporations

have their faults, a great many of them; they are human, but the majority of them are square and desire the good will of the public. They depend upon the public for its support. But they are just as liable to injury, fraud, and wrong-doing from the public as the public is from what it considers the corporations are doing to it. So when this matter was worked up so thoroughly by the commissioner and his friends and confrères, they insisted that there should be payment. I regret that we ever acceded to it; while the amount of money involved is a very small matter, yet if we were back where we were then I should positively advise the company against it. They put it down in the agreement as "clerical work." I am not going to call it by any ugly name, because I have too much regard for my friend the commissioner, but you can insert the word to suit yourselves. We went along with all this hurrah, and almost every official in the city of Somerville thought there was a chance to damn the Edison Company. We were threatened with injunctions, and I was almost afraid I was going to be arrested for something I hadn't done, but through the calm spirit of our friend we were finally led out of troubled waters to peace. Now, some people cry for peace, some people fight for peace, and some people buy peace, and that is just exactly what the Edison Company did in Somerville. And yet there is no peace; there is no such thing as peace, and that is as far as I care to go to-day. I just want to say that I have meant every word I have said about Merrill; I am going to sing his praises every chance I get, but I am not going to sing the praises of some of his confrères, among whom was a certain official — I won't mention any name — who, when we were putting our wires underground through Broadway in Somerville, at a certain place in the street ordered us to lay a 12-duct line carrying 6 900 volts square on top of their water main. We protested in the strongest manner possible against such a thing as that, but we were forced to do it. Now, what will be the result if any trouble comes? Will he be to blame? Oh, no. The corporation will be the one which will have to suffer.

Mr. Joseph W. Cowles. Mr. President and Gentlemen, I have been somewhat embarrassed by Mr. Lott's kind words, and at the same time I have been reminded of the remark of a gentleman

who on one occasion, when a few nice things had been said about him, remarked that he always did believe that a few ounces of taffy while living were worth tons of epitaphy when dead. So I accept the few ounces of taffy for what they are worth.

I do not know that I can say anything of general interest on this very important subject which is before us, particularly that branch of the subject which has been dealt with so exhaustively in Mr. Merrill's paper. However, as I assured Mr. Merrill it would give me pleasure to be present here and to give any information on the subject which might be within my power, I will be very glad to do so.

When the Edison Company decided four years ago to ground all alternating current services — and, by the way, by a peculiar coincidence I noticed this morning that it was just four years ago to-day that the rule went into effect that all services for house wiring connected with the alternating current lines of the company should from that date be grounded in an approved manner, — they were convinced that they were taking a most progressive and thoroughly practicable and most beneficial step, and we are far more convinced of it to-day than we were then.

Although the idea of grounding secondaries was by no means new, as has been shown by Mr. Merrill's paper, — it had been introduced in Somerville nearly three years previously, — it had not been put into effect except to a very limited extent. It had been done in individual cases for individual reasons, but it was a comparatively new move and little had been done toward accomplishing a general grounding. In this, as in all new moves, some pioneering and some missionary work was necessary, and the path of the company was not altogether free from obstacles, as has been referred to by Mr. Lott. But four years ago to-day the rule went into effect that from that date no services would be connected by the company in their alternating current districts which were not grounded by an approved method. True to its convictions, the company set forth at once to provide the necessary grounding for the then existing customers at its own expense. Applying that principle throughout its entire system, which was then broadening at a rapid rate, it proceeded to install over 5 000 ground wires at its own expense for its then existing customers,

thus showing the firm conviction on the part of the company of the desirability and importance of the work.

Now, as to the objections, and the nature of them, which have been raised. There was a considerable feeling of opposition from the customers themselves at first, and more particularly certain electrical contractors took great pleasure in presenting to the minds of the public that the company was asking the customers to protect themselves against carelessness, or whatever they might choose to call it, on the part of the company; in other words, that the company was asking the consumers to pull its chestnuts out of the fire. Granting, gentlemen, that accidents may happen even due in some way to the fault of the company, the chances of such accidents are almost infinitesimal compared with accidents which may happen for which the company is absolutely unresponsible, which the company has absolutely no power to prevent, such as the effect of high winds, storms, sleet, falling trees and branches, etc., so that the company is not expecting the customer to pull its chestnuts out of the fire, or, in other words, to do what the company itself ought to do.

Certain contractors, also, found great pleasure, apparently, in opposing the idea because of the slight additional expense in the cost of wiring, due to the additional wire required for grounding. This expense is so slight, and the objection so trivial, that it hardly warrants further mention at this time.

On the part of water companies there naturally arose at first a question as to the advisability and safety of doing this. This was most natural in view of the troubles which do exist, under certain conditions, from electrolytic action, as has been set forth in Mr. Knudson's paper. But it should simply require a few words of explanation to make clear the entirely distinct and different class in which alternating current grounding comes from that which has been recognized for so many years as in some cases causing serious trouble. To an untechnical mind it is not easy to make clear the difference between the alternating current and the so-called direct current, and I would hardly dare attempt at this time to explain it, even though it might be interesting to do so. But the explanation of the whole question is in the fact that in alternating current distribution we are not dealing in any way

with the currents of high volume and of constant polarity which are dealt with in some classes of electric business. So, as has been stated on the records of the National Underwriters Association, and as was stated in the report of the expert employed by the city of Somerville, there is no danger to be expected to the pipes from any electrolytic action in the case of alternating current supply. There is no current over the ground wire whatever under normal conditions. If, in case of emergency, and that is the very purpose for which the ground wire is there, there may be an instantaneous flow of current, it is of small volume, infinitely small, compared with what there is in other classes of the business, and it is of alternating polarity, so that the possibility of electrolytic action or electrolysis from this current is entirely unknown. It is not to be expected theoretically, and is entirely unknown in practice, as Mr. Merrill has stated in his report.

In addition to the 5 000 ground wires originally installed by the company for the then existing customers, grounding connections have been continuously made, not only in Somerville, but practically throughout the entire territory of the Boston Edison Company, which is not small in extent, as you all know. I am not prepared to say at this minute how many such connections have been made, but for a guess I would say at least several thousands. So if the Boston Edison Company to-day, with approximately 10 000 services grounded on its system, dating back over a period of four years, is able to show you no injurious effect upon the water systems due to the passage of its current over these grounding connections, is not the proof conclusive that there is no danger to be feared?

Perhaps I answered Mr. Doyle's question when I stated that we must all recognize that accidents may happen. They may happen from numerous causes. By accidents, I mean crosses of lines, crosses between lines of high potential and lines of low potential, and those may be due to any one of the reasons which I have already mentioned, — falling trees, storms, cyclones, etc., — so that it is in the interest of safety, both of life and property, that some means shall be provided for the meeting of those emergencies which may arise. They fortunately are so few in number as to be almost insignificant, but so long as we cannot ignore them

absolutely, but must recognize their possibility, why is it not in every way in line with common sense and good judgment, why is it not in every way essential, to provide some means for taking care of possible emergencies? That is the reason why the wires should be grounded.

Now, as to connecting in the cellar rather than outside of the cellar wall. It is purely a question of feasibility. The water service pipe inside the cellar wall is perfectly accessible, not only at the start, but forever after, for as frequent inspection as may be called for. Connection on the outside of the cellar wall — never mind the expense of it; that may be of no consideration — is inconvenient, it is awkward, necessitates digging up the front lawn to make the connection, and then the connection is hidden from view, so that it is not open for subsequent inspection and care. That is the reason why the connection should be made on the inside of the cellar wall, chiefly for the sake of subsequent inspection, in order that the connection may be watched and taken care of just like any other part of the system to which our attention is being continually given.

With reference to the point mentioned of the resistance of joints, through shut-offs, meters, etc. One of the points insisted upon most rigidly by the underwriters, and by all local insurance inspection bodies, is that the connection shall be made in an approved manner, that is, by means of an improved clamp, and then on the street side of all disconnecting fittings. Under no ordinary conditions are connections allowed inside of the shut-off, the meter, or any other disconnecting fittings. So that with the connection made immediately inside the cellar wall, within 10, 12, or 15 inches of where it would be if it were made on the outside of the wall, you are in every way as well connected, and you avoid all of the objections which I have pointed out to making the connection outside. To attempt to make such connections generally inside, that is, on the house side, of shut-off valves, meters, etc., could not be defended from any standpoint. It is not attempted, and no attempt has ever been made to defend it. So for those reasons the proper and logical place for the connections to be made is in the cellar, as close to the cellar wall as possible.

I listened to Mr. Knudson's paper with extreme interest, and

it brought out much information as to existing conditions. But I wish to emphasize this point: That the conditions dealt with by Mr. Knudson in his paper are in every way different, and in no way similar, to the conditions pertaining to and dealt with in Mr. Merrill's paper. I simply wish to leave this word of warning with you, that in the matter of grounding alternating current secondaries you do not confound in your minds any relation between the conditions surrounding that question with the conditions so interestingly set forth in Mr. Knudson's paper.

There is a certain gentleman in the electrical fraternity of New England who is extremely optimistic, and on a certain occasion he made the statement that the only difference between an optimist and a pessimist was one or two cocktails. Well, gentlemen, I will leave it to my neighbors that my optimism has nothing to do with cocktails, either here or elsewhere, but I can assure you from the heart that personally, as well as in behalf of the company, we are even more optimistic to-day as to the benefits to be derived from grounded alternating secondaries than we were four years ago.

Mr. R. C. P. Coggeshall.* May I ask one question? How would you treat a case where the meter is set outside the house, on the lawn? Sometimes it becomes necessary to do that.

Mr. Cowles. Those cases have arisen, but they are very few in number. They have been dealt with, according to the judgment of the local board of inspection. In some cases the connection has been carried outside, that is to the street side of the water meter. More generally, however, it has been in these rare cases connected inside of the meter, that is, accepting those cases as the exception to the rule, and believing that on the whole the chances of trouble were not sufficient to warrant the more difficult task of going back to the street side of the water meter. The question has been settled in each case, so far as I know, according to the judgment of the local board of inspection.

Mr. Frank L. Fuller.† I would like to ask whether in a special case, when the meter is set outside, there couldn't be something in the nature of a by-pass or conductor put around the meter? The

* Superintendent Water Works, New Bedford, Mass.
† Civil Engineer, Boston, Mass.

meter has to be set so it can be read, and why couldn't a by-pass, for the conducting of the current, be put around the meter?

Mr. Cowles. It seems as if that would accomplish the same result.

Mr. Foss. My question apparently was not understood, and I will try to make it clearer, regarding the grounding on the service pipe in the house or outside. I meant on the main outside, not using the service pipe at all. It occurred to me that possibly it would be much better to ground right on to the main pipe itself rather than on to the service pipe. And then I brought up also the question of the effect of lightning working into a house. Regarding the underwriters' rules, unfortunately they are not always obeyed. I found about a year ago, in the city of Newark, in a large Catholic church, the secondary had been grounded on the house side of the gas pipe, inside of the meter, and also on a water pipe in another part of the city inside the water meter.

Mr. John H. Flynn. Did I understand Mr. Cowles to say that the connection should be made on the street side of the stopcock, to get outside of all disconnecting joints? Is that the practice? .

Mr. Cowles. I said it invariably should be on the street side of the disconnecting fittings, having in mind the usual water shut-off and fittings on both sides of the meter.

Mr. Flynn. It is good water-works practice to have at least from one to three such disconnecting joints between the main pipe and the stopcock inside the building. Now, if it is not good policy to put the connection on the outside, why is it good policy to put it in at all? You have the same conditions existing on the outside that you have on the inside.

Mr. Cowles. Possibly I implied the idea, although I did not intend to, that the reason for connecting on the street side of all disconnecting fittings was because of any fear of the effect upon the fittings. Not at all; absolutely not. It is rather to get on the street side of any fitting which may perchance be disconnected, if, perchance, the water meter may be taken out for any reason, temporarily or otherwise, and the water shut off for a day, or for an hour, or for any time. The idea is to get a connection made back of anything which may reasonably be expected to be disconnected, cut off, at some time, and by no means because of any

fear of the effect upon those fittings. There isn't anything to fear there. It is simply a question as to the likelihood of the metallic circuit being opened, broken, for any reason, temporarily or otherwise.

Referring again to the question of connecting to the mains. Such connections are much more difficult to make at the start, and it is infinitely more difficult and more unsatisfactory to maintain any sort of inspection of them. They involve buried connections. We never know what may have happened. So it is simply a case of practicability.

As regards lightning, it should be borne in mind that the ground wire is connected to the service ahead of, that is, on the street side of, the service switch and cut-off, a sample of which is on the table, so that any high potential current, lightning or otherwise, coming on that line is conducted to the earth before passing through the service switch, and, therefore, before passing inside the house at all.

Mr. Foss. If that ground is sufficient for lightning or for high voltage before it gets to the switch, why do you need the other ground inside for the low potential circuit? If you already have a ground before you reach the basement which is sufficient for lightning and high voltage, why do you need the additional ground inside the basement?

Mr. Cowles. There is only one ground in question, sir. I am speaking of a ground wire which extends from the service wires to the water pipe. One end is connected to the service wires on the street side of all shut-offs for exactly the same reason that it is connected to the water pipe on the street side of all shut-offs, so as to eliminate the possibility of the circuit being opened, broken, through either electric switches or water shut-offs of any kind.

Mr. Charles W. Sherman.* I should like to ask Mr. Cowles whether, in view of the difficulty of making and maintaining inspection of house ground connections, a single ground of adequate capacity from the secondary coil of the transformer to a main water pipe would not provide an equally adequate safeguard for all the services from that transformer.

Mr. Cowles. If such a ground wire of ample capacity could be run and maintained with the absolute assurance that at all times

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and under all conditions it would be in first-class condition, both as to the connections at both ends and in its grounding at the other end, such a wire would be very satisfactory. But, perhaps, you notice there are a great many " ifs " in there, and it is the " ifs " that kill it. In other words, you are putting your eggs all into one basket and hoping and trusting that the basket won't break. That is contrary to good judgment in any line of business, whether it is the electric business, water business, or any other. This method has been tried faithfully and with very poor success as compared with the success of the multiple ground system. One is the case of a single ground, and the other of multiple grounds. You can't have too many. A dozen is better than one, simply because you don't want all your eggs in one basket.

Mr. Sherman. Of course if it has been faithfully tried and proved wanting that is an ample justification for not using that system. I believe, however, it was Mark Twain who, in his " Revised Proverbs," said, " Put all your eggs in one basket, and then watch your basket."

The President. We have another official of the Boston Edison Company here, who was formerly a water-works superintendent, as I understand, — Mr. F. Ellwood Smith, suburban sales agent of the company. We would like to hear from Mr. Smith.

Mr. F. Ellwood Smith. Some twenty years ago it was my privilege to attend a meeting of this body, as a guest of a member in whose employ I was at that time, and I passed a very enjoyable afternoon, and in former years I enjoyed very much the reading of some of the proceedings of this Association. It is sometimes said that it is better to have been a " has-been " than never to have been at all, and I am very glad that I have been a water-works man.

Referring to the subject of the grounding of secondaries, I was the person who first brought the matter to the attention of my friend Mr. Merrill some seven or eight years ago. It is a subject which at that time had been agitated among electrical companies, and one which has been talked about and argued over as much as, if not more than, any other one subject that has been before our conventions year after year. The grounding has been recommended by the insurance rules for a great many years, and while the electric light people have, I think, almost universally agreed for

a long time that it is desirable and ought to be done, the one question has been how to do it.

From what has been said here this afternoon you might get the impression that it was the Edison Company alone which was doing this. That is not true, by any means, because, as I say, the subject has been discussed at our National Electric Light Association meetings and other gatherings of electric light people throughout the country, and they are all interested in it, and the wires are being grounded in a great many places.

At the time I first thought of the matter and took it up with Mr. Merrill there was, of course, the option of putting in ground plates or attaching to water pipes, or some other way of getting a suitable ground. When the city concluded that it was not advisable to allow us to attach our ground wires to their pipes, I tried to see what I could do in the way of ground plates. I visited some places where ground plates had been used, and consulted with electricians, to find what results they had obtained. I found where they had grounded transformers and secondary networks by drilling down into the ground and putting in pipes and plates that in some cases were satisfactory and in other cases were not satisfactory. In some cases where the work had apparently been all right when it was first put in, after being installed for several months, upon making tests, it would be found that there was really no ground, that there was no moisture in the ground at that point at that time; so that this method was not a certain and sure one of making a ground.

I took up the matter of driving pipes or setting plates in various portions of the city of Somerville, and got some estimates from people for doing that work. I found that I was up against it in a great many places, because after going down a few feet there was ledge, and I found that to ground my secondary networks and my transformers in Somerville, in a great many cases I would have to practically drill an artesian well, which was, of course, entirely out of the question. And while I at that time fully believed that it was a proper thing for the protection of the public, and a thing which ought to be done, I was obliged then to give it up. Since that time it has been talked of from year to year among electrical people, and now it is universally agreed that it is something which

ought to be done, and I am very glad that our company has succeeded in having these grounds on practically all of its services.

W. E. Foss (*by letter*). In connection with this subject, a brief account of a fire which occurred in Bridgewater, Mass., on April 3, and of the conditions revealed by an investigation following the fire, may be of interest.

An electric car had stopped on the Old Colony Street Railway tracks in Central Square early in the forenoon, and while the conductor was reversing the trolley pole the tag rope broke and the released trolley pole flew up and simultaneously made contact with the trolley wire and with the lead sheath of an aerial telephone cable which was suspended across the street a few feet above the trolley wire. The telephone cable extends a short distance south on the west side of the square and enters the telephone exchange, located on the second floor of a wooden building. A store is located in the basement and the first floor of this building, and the Masonic Hall is located on the third floor.

Simultaneously with the flash which accompanied the contact of the trolley pole with the telephone cable in the square a fire was discovered in the basement of the Masonic Building. Through the efforts of the firemen the fire was confined to the basement and extinguished after causing a loss of a few thousand dollars.

Another fire was discovered in the southwest corner of the Masonic Hall on the third floor, and was readily extinguished because of the non-inflammable nature of the material at this point.

Investigations made after the fire showed that the telephone cable sheath had been grounded on a $\frac{3}{4}$-inch galvanized iron pipe driven into the dry earth outside of the main building, but under a covered flight of stairs leading to the upper floor of the building and located in the narrow space between the Masonic Building and the adjoining building. This ground pipe was found melted off at a point about $1\frac{1}{2}$ feet below the surface of the ground, where it passed close beside an abandoned wrought-iron gas pipe which entered the northeast corner of the basement. The gas pipe was also melted away for a length of about 3 inches at this point. A hole about 2 inches long had been fused into the gas pipe in the basement at a point where it crossed over a short nipple on the

water service pipe, which also had a hole melted in it at this point.

In the southwest corner of Masonic Hall, where fire was discovered on the third floor of the building, the gas pipe was located near one of the wrought-iron heating pipes. A hole about 2 inches in length had been fused in the gas pipe, and the heating pipe also showed the effects of fusion at this point.

Two serious breaks had previously occurred in the main water pipes in the square early in 1906 as a result of electrolysis from the street railway return current, and as a remedy the main pipe was metallically bonded to the rails by the railway engineers.

Under these conditions the cause of the fire is evident. When the positive side of the street railway circuit became connected to the telephone cable sheath, a large current of electricity flowed over the sheath, ground pipe, gas pipe, water pipe, and the metallic bond to the rails because of the low resistance which had been made between the water pipe and rails by the metallic bond. This current was sufficient to form the large electric arcs which burned off the ground pipe and gas pipe and fused the holes in the gas and water pipes and set fire to the adjacent inflammable material in the basement and in the Masonic Hall.

The experience in this case seems to emphasize the desirability of keeping all ground connections off of the service pipes which enter the buildings, and shows how serious damage does result when grounded currents enter a building and how this danger is greatly increased by bonding the water pipes to the rails to prevent electrolysis.

Mr. F. A. McInnes * (*by letter*). Electrolysis is a word of unpleasant sound to water-works men, yet under certain conditions at least they must consider its possible action in the matter of grounding electric lighting circuits to water pipes in houses.

The following case occurred in Boston recently:

Four houses were lighted on one secondary circuit, a ground being made in each house to service pipe; the water main in the street carried an electric current and was at a higher potential than the car rails and a Boston Elevated Railway return conduit, both rails and conduit being located between the water

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pipe and the houses: under these conditions part of the current on the water pipe flowed through the circuit formed by the services, ground wires, and lighting wires. The trouble occurred in the service pipe by which the current returned from the house to the water main, it being destroyed under the Boston Elevated Railway conduit; at this point a path of sufficiently low resistance evidently caused a part of the current on the service pipe to " jump " to the conduit, and electrolysis of the pipe resulted. Actual measurements showed a flow out from the house towards the conduit and a diminished flow in the same direction between the conduit and main pipe. There can be little doubt that the ground wires at least hastened the destruction of the service pipe in this case. Until further assurance of safety can be given, it is unwise to allow secondary lighting circuits to be grounded to service pipes in houses in positive sections of a distribution system, i. e., in sections where the water pipes are at a higher potential than car rails and other structures; if such grounds are made, a larger flow of electricity upon the service pipes must result and increased danger of damage from electrolysis is inevitable.

COVERED RESERVOIRS.

Some Experiences in the Use of Concrete in Their Construction and in making Them Watertight.

BY FRANK L. FULLER, CIVIL ENGINEER, BOSTON, MASS.

[*Read at September, 1903, Convention.*]

Water supplies from ground water or springs require the use of covered distributing reservoirs into which no light can penetrate if the growth of algæ is to be prevented.* Where ground at a sufficient elevation can be secured, the covered masonry reservoir, generally set partly under ground, is preferable. In many localities the lack of sufficiently elevated land compels the use of a steel or iron standpipe. This paper has to do with covered reservoirs only, and not covered tanks or standpipes.

An interesting paper on "Covered Reservoirs" was read at the Providence, R. I., meeting of this Association in June, 1888, by Charles H. Swan. Mr. F. C. Coffin also read a valuable paper before the Association on "Covered Reservoirs and Their Design," at the May meeting, 1899, dealing especially with the engineering features of their construction.

The town of Wellesley built an open distributing reservoir in 1884 for the storage of ground water. When first filled the water was perfectly transparent, but in a few days it lost its transparency and became clouded. This occurred whenever the reservoir was cleaned and refilled, which was generally about once in two years, when from one to two feet of very dirty water, of a greenish color, was removed from the bottom.

No very disagreeable taste was noticed, probably because pumping took place every day, and consumers were supplied with a considerable amount of fresh water.

In 1897 a covered reservoir was built adjacent to the original

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* See report of G. H. Parker, biologist, Massachusetts State Board of Health, dated January 4, 1888; reports of Engineer and Chemist, Massachusetts State Board of Health, 1890; "A Study of Algæ Growth in Reservoirs and Ponds," F. F. Forbes, Journal N. E. W. W. Association, 1896.

Covered Distributing Reservoirs in New England.

Built during Year	Town or City	Engineer	Form	Inside Dimensions	Depth of Water	Capacity U.S. Gallons	Wall: Thickness Top	Wall: Thickness Bottom	Wall: Material	Piers: No.	Piers: Size	Piers: Height	Piers: Material	Piers: Distance Apart on Centers	Roof: Form	Roof: Span	Roof: Rise	Roof: Thickness At Piers or Circumference	Roof: Thickness At Center	Roof: Material	Depth of Depression over Piers	Total Cost	Cost per 1000 Gallons	Remarks
1888	Kingston	A. H. Howland	Circular	Diameter 50' 0"	18' 0"	264 000	1' 4"	2' 0"	Brick											Wood Supported on Iron Trusses		$4 [illegible]	$15 [illegible]	[illegible] Engineering and Inspection
1890-1	Newton	A. Fteley, A. F. Noyes	Rectangular	Top 125' x 172', Batter 1:12	14' 6"	2 298 000	5' 2"	7' 10"	Rubble Masonry, Rosendale Cement	139	20" x 20"	15' 6" to 16'	Brick, Rosendale Cement	10' 0"	Lintel and Covering Arches	Lintel Arches 10' 0", Covering Arches 10' 0"	Lintel Arches 10' [illegible], Covering Arches 10' [illegible]	18"	8"	1" Brick, 4" Concrete		36 000 00	15 6[illegible]	Includes Engineering and Inspection
1891	Franklin, N. H.	F. L. Fuller	Circular	Diameter: Top 71' 0", Bottom 69' 0"	17' 8¼"	504 900	2' 0"	5' 0"	Rubble Masonry	30	12" x 12"	16' 2" and 16' 4"	Brick	7' 0¼"	Dome and Covering Arches	Dome 23' 0", Covering Arches 11' 0"	Dome 3' 3", Covering Arches 1' 0"	8"	[illegible]	Brick		9 [illegible]	18 [illegible]	[illegible] Engineering and Inspection
1892	Brookline	F. F. Forbes	Square	Top 94' x 94', Bottom 91.33 x 91.33	19' 2"	1 200 000	4' 0", 3' 8"	9' 6", 8' 6"	Roxbury Pudding Stone	49	24" x 24"	17' 6"	Brick	12' 0"	Lintel and Covering Arches	Lintel Arches 10' 0", Covering Arches 10' 0"	Lintel Arches, Covering Arches 1' 0"	20"	8"	4" Brick, 4" Concrete		29 808 01	24 [illegible]	Includes Supervision but no Engineering
1893	Methuen	F. L. Fuller	Circular	Diameter: Top 95' 0", Bottom 93' 0"	19' 8¼"	1 013 200	2' 6"	5' 0"	Rubble Masonry	60	16" x 16"	18' 1½", 18' 1" and 18' 4½"	Brick	7' 10½"	Dome and Covering Arches	Dome 23' 0", Covering Arches 11' 0"	Dome 3' 3", Covering Arches 1' 6"	8"	8"	Brick		17 [illegible]	17 [illegible]	Includes Engineering and Inspection
1895	Fiske Warren, Harvard	F. L. Fuller	Circular	Diameter 22' 0"	12' 0"	34 100	2' 6"	4' 0"	Rubble Masonry						Dome	22' 0"	3' 0"	8"	8"	Brick			..	
1895	Boston	City Engineer and C. E. Putnam	Rectangular	168' x 67'	12' 0"	800 000	8"	8"	Concrete	80	16" x 16"	10' 4"	Brick	10' 0"	Lintel and Covering Arches	Lintel Arches 8' 8", Covering Arches 8' 8"	Lintel Arches 1' 0", Covering Arches 1' 0"	10"	8"	Concrete		27 [illegible]	34 [illegible]	
1896	Winchendon	F. L. Fuller	Circular	Diameter: Top 71' 0", Bottom 69' 0"	17' 8¼"	504 300	2' 6"	5' 0"	Rubble. Rosendale Cement	30	12" x 16"	16' 2" and 16' 4"	Brick	7' 6¾"	Dome and Covering Arches	Dome 23' 0", Covering Arches 11' 0"	Dome 3' 3", Covering Arches 1' 6"	8"	8"	Concrete		8 477 [illegible]	16 8[illegible]	Includes Engineering, Rock Excavation and Inspection
1897	Hospital for Epileptics, Monson	F. L. Fuller	Circular	Diameter 11' 0"	19' 0"	178 000	2' 6"	4' 6"	Rubble Masonry		.			..	Dome	11' 0"	4' 0"	10"	8"	Concrete		5 81[illegible] 40	32 [illegible]	Includes Engineering, Rock Excavation and Inspection
1897	Wellesley	F. C. Coffin	Circular	Diameter 82' 0"	15' 7"	600 000	2' 0"	3' 4"	Rubble and Concrete	20	24" x 24"	15' ¾" and 15' 5"	Concrete	14' 0"	Elliptical Groined Arches	12' 0"	2' 6"	10"	8"	Concrete		10 414 86	17 [illegible]	[illegible] Engineering and Inspection
1897	Groton	C. A. Allen	Rectangular	107' x 90'	9' 0"	500 000			Slopes 2 to 1, lined with 12" of Concrete	15	20" x 20"		Brick		Flat							8 621 72	17 24	Includes Engineering and Inspection
1901-2	Newton	I. T. Farnham	Rectangular	105' 2½" x 127'	14' 6"	2 219 100	5' 2"	7' 2"	Rubble Masonry	140	20" x 20"	15' 1"	Brick	11' 8" and 11' 10½"	Flat, Steel and Concrete	10' [illegible] and 10' 0"		7"	7"	Steel and Concrete		36 000 00	16 2[illegible]	[illegible] Engineering and Inspection
1902	Natick	F. L. Fuller	Rectangular	Top 212' x 217', Bottom 154' x 190'	17' 3"	4 280 000				109	20" x 20"	15' 6" to 16' 6"	Concrete	15' 2"	Elliptical Groined Arches	13' 6"	2' 9"	39"	6"	Concrete	0' 6"	[illegible] 1 140 72	7 27	Work [illegible] Slope [illegible] Rock Paving [illegible] Mortar. Includes Engineering and Inspection
1903	Brookline	F. F. Forbes	Rectangular	333.3' x 102'	21' 0"	6 507 800		4' 0"	Concrete	264	20" x 20"	20' 0"	40 Concrete, 224 Brick	13' 8"	Elliptical Groined Arches	12' 0"	2' 6"	36"	6"	Concrete	0' 10"	71 2[illegible] 56	11 40	Includes Supervision [illegible] Engineering
1903	Lowney Chocolate Co., Mansfield	F. L. Fuller	Circular	Diameter 41' 0"	11' 5"	100 500	2' 6"	4' 0"	Concrete						Dome	41' 0"	4' 0"	10"	8"	Concrete				
1903	Shirley	F. L. Fuller	Circular	Diameter 41' 0"	20' 0"	197 500	2' 0"	3' 5"	Concrete						Dome	41' 0"	4' 0"	10"	[illegible]	Concrete		5 1[illegible] 98	26 0[illegible]	Includes Engineering and [illegible]
1903	Bristol, Conn.	F. C. Coffin	Square	75' x 75'	8' 0" to 14' 6", 14' 0" to 16' 6"	500 000	2' 0"	4' 0"	Concrete	16	24" x 24"	9' 0" to 13' 6"	Concrete	15' 4"	Elliptical Groined Arches	13' 4"	2' 9"	10"		Concrete	1' 0"	6 071 00		[illegible]
1904	Walpole, N. H.	F. C. Coffin	Circular	Diameter 50' 0"	17' 0"	250 000	2' 0"	3' 0"	Rubble Masonry	13	16" x 16"	17' 0"	Concrete		Flat					2" Hemlock and Paroid Roofing		2 [illegible] 00	10 0[illegible]	
1905	Uxbridge	F. L. Fuller	Circular	Diameter 71' 0"	17' 8¼"	518 900	2' 6"	4' 0"	Concrete	30	12" x 16"	16' 8" and 16' 10"	Concrete	7' 6¾"	Dome and Covering Arches	Dome 23' 0", Covering Arches 11' 0"	Dome [illegible], Covering Arches 1' 6"	8"		Concrete		12 171 4[illegible]	23 4[illegible]	[illegible] Engineering, Rock [illegible]
1905	Northfield, Vt.	F. L. Fuller	Circular	Diameter 40' 0"	20' 1½"	249 800	2' 6"	3' 6"	Concrete				Concrete		Dome	40' 0"	4' 7¼"	10"	[illegible]	Concrete		7 409 11	29 6[illegible]	Includes Engineering, Rock [illegible]
1906	Franklin, N. H.	F. L. Fuller	Circular	Diameter 46' 0"	20' 0"	248 000	2' 0"	3' 0"	Concrete				Concrete	.	Dome	46' 0"	4' 7¼"	10"	[illegible]	Concrete		[illegible]	14 1[illegible]	[illegible] Engineering and [illegible] Rock Excavation
1906	Northfield, Vt.	F. L. Fuller	Circular	Diameter 40' 4½"	20' 0"	251 800	2' 6"	3' 6"	Concrete				Concrete		Dome	40' 3½"	4' 7¼"	10"	[illegible]	Concrete		7 [illegible] 92	31 1[illegible]	Includes Engineering, Rock [illegible]
1906	Dracut	A. E. Lyford	Circular	Diameter 50' 0"	17' 0"	250 000	1' 0"	2' 0"	Concrete	13	16" x 16"	18' 0"	Concrete	12' 6"	Conical, rises 6" from Circumference to Centre Pier			2"		2" Hemlock on 6" x 10" Purlins, Ruberoid Roofing		[illegible] 120 00	12 4[illegible]	[illegible] Engineering, R[illegible]

open reservoir, which was disconnected from the distribution system, but held in reserve in case of fire.

As there appeared to be no necessity for so doing, the new reservoir was not emptied and cleaned for about six years. With the exception of a small amount of sand, which probably got into the pipes at the time they were laid, but little material was found requiring removal. The condition of the bottom of the covered reservoir was very different from that of the open one, whenever it has been examined.

The experience of Franklin, N. H., with a covered reservoir, holding a reserve of ground water, has been equally satisfactory.

In addition to the necessity of a covered receptacle for ground water, its advantages are very great. Not only is all light excluded, but also much objectionable matter, such as dust, leaves, and whatever may be thrown into the water by careless or malicious persons. The water as it comes from the ground or spring usually has a temperature of from 42° to 50° F. Under these conditions there will be no ice in a covered reservoir, even in the coldest weather, and in summer much of the natural coolness of the water will be retained. This approach to uniformity of temperature is a decided advantage during both summer and winter. The water as it comes from the ground is clean and wholesome. It can be kept in this condition only by being stored in a clean and closed reservoir of indestructible masonry. Those in charge of a water-works system or department have a feeling of security when the water is taken from the ground within a territory well protected from intrusion and contamination and pumped or delivered by gravity into such a reservoir.

The fact of the necessity and advantage of covered reservoirs for ground water supplies being established, it may be profitable to give some consideration to the forms of construction and material which have been employed. To do this as concisely as possible, a table has been prepared which attempts to give some of the most important details of all the covered reservoirs in New England. (Table 1.)

The list is probably not complete, as the time in which it has been prepared has been limited, and particulars regarding some of the reservoirs have not yet been obtained.

Covered reservoirs must of necessity be built of masonry and, therefore, at greater expense than open ones, where the excavated earth is used to form the embankments. The table referred to gives the cost of covered reservoirs per 1 000 gallons of storage. The following table gives similar figures for a few open reservoirs.

Date of Building.	Town.	Capacity, Gallons.	Cost.	Cost per 1 000 Gallons.	Remarks.
1884	Wellesley, Mass.	1 151 500	$15 786.00	$13.77	Includes cost of gate house.
1886	Ware, Mass.	1 558 000	13 657.00	8.77	No gate house.
1900	Fiskdale.	200 000	4 370.00	21.85	No gate house.

Those at Ware and Wellesley were built for ground water before much was known of the necessity of covered ones. If built to-day, both, no doubt, would be covered.*

Waterproofing of concrete is an important and interesting subject, but one upon which there is much diversity of opinion. Many preparations and compounds, mostly intended for application to the surface to be waterproofed, have appeared, but the writer has had no experience in their use.

It has seemed to him that the use of the best material, with a proper surplus of cement and sand over the voids in broken stone or screened gravel, thorough mixing, intelligently done with honest labor in placing, including the greatest care in cleaning old work, when new concrete is to be added to it, was of great importance. With the addition of a plaster coat composed of one part cement and one or two parts of sand, from one eighth to one fourth of an inch in thickness, applied by a good workman with a trowel, in a thorough manner, followed by a second and thinner coat of neat cement, there should be little or no leakage. If there is, coats of neat cement of the consistency of gruel, applied with a brush, will generally cover any minute pores which escaped filling by the plaster coat.

The thorough troweling of these plaster coats upon a surface which has been left somewhat rough reduces them to a compact mass of fine texture. Each brush coat that is added offers addi-

* Since writing the above, the town of Wellesley has voted to cover its open reservoir with a concrete roof at an expense not exceeding $13,000.

tional resistance to the entrance of water into and through the whole thickness of the wall.

In the reservoirs the writer has constructed very satisfactory results have been obtained by this method, although, as the reservoir is apt to be finished late in the season, and is needed at once in the operation of the system, but little time can usually be had to test its tightness.

A careful test of the Wellesley covered reservoir built in 1897, made in 1907, and lasting for twenty-three hours, showed absolutely no drop in the water surface. The reservoir was shut off from the distribution system and the old open reservoir used during the test. The interior of this reservoir was treated in the manner described.

The Uxbridge reservoir, upon its completion and before any inside treatment, was found to leak at the rate of about 19 gallons per minute. A coat of hot coal tar pitch was applied to the bottom and sides, but it did not adhere well.

Coats of alum and soap or the Sylvester process were then used upon the walls, but without very satisfactory results.

Finally, the water commissioners decided to build a 4-inch brick wall parallel to the concrete wall of the reservoir, leaving a space of about one-half inch between the two walls. As the brick wall was built up the space was filled with hot coal tar pitch. The brick wall and thin lining of pitch were carried slightly above high-water level.

The cost of this work and of applying a thin coat of coal tar pitch over the bottom with a layer of Portland cement concrete two inches thick over it, was about $2 350.

On the completion of this work, no leakage could be detected.

The addition of a small amount of hydrated lime, varying from 5 to 10 or 15 per cent. in weight, of the weight of cement used, has been advocated, but has not been used by the writer. The leaner the mixture, the greater the amount of hydrated lime required. The hydrated lime, from its extreme fineness, tends to more fully fill the voids in the concrete, thus increasing its density and its watertightness. The addition of the hydrated lime reduces the strength of the concrete, but this reduction can be provided for by increasing the volume of concrete.

Mr. Bertram Brewer, city engineer of Waltham, Mass., and a member of this Association, describes its use in the building of a large standpipe or tank for use as a distributing reservoir in that city, in a paper read before this Association, September, 1907. This standpipe was built in 1906, and 5.5 per cent. of hydrated lime was used. Mr. Brewer believes the lime to be a "valuable adjunct," but emphasizes the great importance of careful mixing and placing, and of thoroughly cleaning the surfaces of old concrete before new concrete is added. Mr. Brewer also used Medusa compound, but found it expensive.

Mr. Sanford E. Thompson, member of the American Society of Civil Engineers, read a paper at the annual meeting of the American Society for Testing Materials, at Atlantic City, June, 1908, in which he concludes from experiments he has made on the permeability of concrete that watertightness is increased by the use of hydrated lime. He presents a table showing the leakage in grams per hour through concrete with different percentages of hydrated lime.

All such investigations are of interest and value, and an effort should be made by all those having the opportunity to make them to place the results of their observation on record.

CIVIL SERVICE IN ITS APPLICATION TO THE WATER DEPARTMENT.

BY THE HON. JOSEPH C. PELLETIER, MASSACHUSETTS STATE CIVIL SERVICE COMMISSION.

[*Read March 10, 1909.*]

Gentlemen of the Association: The title given on the notice by your Secretary, "Civil Service in Its Application to the Water Department," rather puzzled me, because I learned that this body was composed of engineers and chemists and men who are deep thinkers, and I wondered if I attempted to apply a dry principle to a wet subject what would happen; and I felt that, not being an expert in practical lines, it might be dangerous for me to attempt such an experiment! Civil Service seems to be considered a dry subject by almost everybody, and that being so, I suppose a water-works association ought to be kind enough to take a little interest in a subject which represents the other side of the question! But as men, most, if not all of you, engaged in the public service, men who represent millions and millions of public money in the management of invested capital, and who spend millions of public money year in and year out, it does seem that you ought to be familiar with a subject like the Civil Service system, and that you ought to support it.

When you talk about Civil Service to a man who is not acquainted with it, a smile plays around his lips and he shrugs his shoulders and prepares at once to listen to a reformer. In these days, when the voice of the reformer is heard in the land, you do not have to come to a distinguished presence like this to hear reformers, and I assure you that Civil Service has little of the reform goody-goody notion to it. It is a practical proposition, and both of the great political parties of this country have had, in their national platforms, on more than one occasion, a plank endorsing the Civil Service system; and most of the great statesmen of our country, from almost the beginning, have endorsed the Civil Service system. One of the most eloquent tributes

ever paid to it came from the lips of our own Webster. This being so, I think we must agree that the Civil Service idea is not that of the reformer, is not that of the complainer, but is something which has a part in the body politic and a law which must have some reason for its being.

The Civil Service system in this Commonwealth, contrary to the popular notion concerning it, has nothing whatsoever to do with tenure of office, and its originators never had any such thing in contemplation. The Civil Service system in our Commonwealth has to do with original selection and original appointment only. The matter of removal or tenure of office has no place in the Civil Service law. There is a law, however, passed some five years ago, not made a part of the Civil Service law of this state, which gives the man discharged the right to be notified in writing with an assignment of the cause, and gives that man a right to be heard. That law was not made a part of the Civil Service law. The practical result of this law is that the man who is discharged is allowed to come before the man who has discharged him and prove that he is innocent, or that he should not be discharged. In other words, the appointing officer does not have to prove his case against the man he discharges. A man is discharged for lack of appropriation, for lack of work, for carelessness; the man then comes before the one who has discharged him; that person sits in judgment upon him, listens to his story as to why the sentence should not go into effect, and then usually confirms the original discharge. Now that is a peculiar situation, but it is no part of the Civil Service law, was not supported by the friends of the Civil Service system, is not administered as a part of the Civil Service system, but it is simply a stray law that passed through the legislature and got on to the statute books of this Commonwealth. Civil Service has to do simply with original appointment to office, and it goes on the theory that every man has an equal right with every other man to hold public office; that if he has the ability, and if he can fill a given position and do the work, he has an equal right with any other man to draw a salary from the public treasury, and that the public service is entitled to the men best fitted for its work.

The old spoils system came down to us from the days when the

commander of the vanquishing army, regardless of the principles which are so familiar to us to-day, on entering a hostage city, felt that the spoils were for him and his men, and it was always recognized that treasure and loot, rape and rapine, were for the victors. There was no law, there was no limitation, to the victor. To him belonged the spoils. That idea came into civil life, and the man who ran for office and was successful, instead of giving his thanks to the friends who had made his success a possibility, sought to reward those men. Not from his pocketbook, not from his personal funds, but he sought to put them in public positions and to have the public treasury pay them for holding those positions. That is the spoils system. There were, of course, some, we will say many, exceptions, but the theory which generally controlled was that the men who had worked at the polls, the men who had brought out the votes, must be paid, and they were paid by being put on the public payroll somewhere and having the public treasury pay them. That was the spoils system.

The consequence was and is that there is always a tendency, where the spoils system prevails, for incompetent men to be given positions, for the underling to feel that he is serving the appointing officer or political boss, to feel that he must do the bidding of that appointing officer or boss no matter what it is. He does not seem to feel or to realize that, while he holds his position, he is serving the public and not the boss. There are few men to-day, I believe, who, when removed from the field of politics, in discussing the situation clearly and calmly, will honestly and sincerely justify the spoils system in public employment.

You hear it said, "The Civil Service is a farce. Do you suppose that I in my private business would be held down to appoint men that somebody else recommended, and be compelled to appoint those men? Can you point out any big business man, any man of affairs, who takes the judgment of some outsider as to the men whom he is to employ in his mill or in his office?" The answer that I make to a question of that kind is: "We certainly would not apply such a system to a man's private business; we would not dream of doing it, and it would probably not work

well if it were done." The Civil Service system, however, is like many a law on our statute books. It is not perfection, it does not always mete out equal justice, there are inequalities in it to be sure; and all that the supporters of Civil Service say is that it is better than the old spoils system, and when the millennium comes, and when the public office holder is absolutely free from the pulling and hauling that in most instances he is subjected to to-day, — when that day comes and politics and the patronage over public positions are not mixed together, when the man holding a public position can feel that he is and actually can remain free of such a thing, the Civil Service system will have ceased to be of any use.

You gentlemen occupy responsible positions in the community, and many of you, doubtless, will say that you are boss in your department and that you wouldn't hold your position unless you could be, and, undoubtedly when you say that you mean it. But are you? Are you men absolutely free? How many men holding positions of importance in public life can honestly say that without a Civil Service system they would be absolutely free to take their choice? How many men here who have held positions before the Civil Service system became law, or who hold them to-day, perhaps, where there is no Civil Service, can say that every appointment they ever made was made to their own satisfaction, of their own choice, upon their own best judgment, and that they never made an appointment to oblige a senator or congressman or somebody of power or influence in the community? Very few, I submit to you, could honestly say "Not guilty." We all know that it is bound not to be so. It is all right to talk about running a municipality like a business corporation. That is an ideal to be gained, an ideal, perhaps, to be striven for, but we haven't reached it yet. We are not running municipalities like private corporations, we are not running the affairs of government as private corporations are run, and it will be many, many a long day before we can do so. Therefore, the Civil Service system steps in and stands between the appointing officer and those who want to be rewarded for work done, and says to the man who wants position: "You can't have this position just because you have a friend in office, but you can come in with every-

body else in this town and take an examination, and after the examination has been held and you have been marked, you will take your place according to what you disclose on your papers."

So the Civil Service system advertises its examinations, invites everybody to come in, and endeavors to make the examinations as practical as can be. Examination papers for your line of business, for instance, the Commission cannot prepare, our chief examiner cannot prepare them, but experts are called in who arrange the questions and afterwards mark the answers to the questions on the special subjects. After a class has been examined and each question marked, every man has the right to see his papers and has a right of appeal if he is displeased with the marking. As a result of the examination we get what we call an eligible list, consisting of men who have been examined and who take their places on that list according to their percentage.

In case of a vacancy, the first three names on the list are sent to the appointing officer, and the appointing officer has the right to select one of them. Now why should that be? Number one man gets 99 per cent., number two gets 95, number 3 gets 85, and the appointing officer takes number three, and has the right to do that under the law. Now, why certify three names? Because it very often happens, or it may happen, that a man who can get 100 per cent. on a written examination is not the man that you want; he is lacking in some capacity that is of extreme value to you in your department; he has some peculiarity that you find out in your first conversation with him, for instance, and you know that he never would get along with the other people in your department. But it is hardly likely, that of the three highest men on the list after an open competitive examination, all will have some such defect. But if it does happen that anything can be properly urged against all of those men, the Civil Service Commission has the right to send other names. So that the appointing officer has before him the names of three men who have been given a practical examination, who have gone in with everybody else in the community and taken their places according to their percentage. The appointing officer has before him the examination papers; he knows how the man can

write, he knows how he can frame a letter, he knows how he stands in arithmetic, and he knows how he stands on the special subject pertaining to the particular business. There are written endorsements on his paper concerning the man. He has all that information, and he can question the man as much further as he desires.

Then what happens? The appointing officer decides to take one of those men. Now, you say, "That is the trouble. We don't like to have any man forced upon us." Well, under the Civil Service law, as I said a few minutes ago, there is no tenure of office. In the first place the man is on absolute probation for a six months' period; he has no rights of any kind; he is simply there, and if you come in some morning and do not like the way his hair is brushed you can tell him to go, because he is merely on probation. That is the law. Of course I do not mean to say that you can act dishonestly in such matters. So you have got six months to try him out, just as you would have to try out any one. Supposing this man comes to you from your congressman, or from some man of influence in the community; you have got to try him out, and it might be a great deal harder for you to discharge that man, coming to you from a friend, than it would be to discharge a man who proves himself poorly fitted, poorly adapted, who comes to you under the Civil Service laws without any pull. So that the objection that these men are forced upon you really does not hold. And after the six months are gone by, as I have said, there is this Removals Act, which makes you, as the appointing officer, both prosecutor and judge.

While in the public mind the Civil Service system means a law that holds a man in office when he has got there, as a matter of fact there is nothing in our law about it, if you will permit me to repeat, and the stanchest advocates of the Civil Service system in this state have always been against any law which would fasten a man in office to the extent that the appointing officer would have to frame an indictment and prove it against him in order to remove him. The friends of Civil Service have been against such a law, or any such a notion in the law, and up to date it has never gone on the statute books.

Another thing that we are being blamed for is the Veterans

Preference Law. You have a position that you really want to fill, and you send to the Civil Service Commission, and at the head of the list is a veteran. Under the law you must take that veteran. If he got 65 per cent. in his examination he goes ahead of the man who got 100 per cent.; no three names are certified, but the veteran goes to you alone, and you have got to take him. Here is a man seventy years of age sent to you for an active position in your department, requiring a vigilant, alert man. You don't want him, but you can't have anybody else under the law. That is a deplorable situation, but that is the situation to-day. But don't blame the Civil Service system for it. When the Veterans' Preference Act was before the legislature, the strongest opponents to the passage of the law were the Civil Service Commission and the Civil Service advocates. It was passed, as you know, by the legislature, but it was put upon our statute books against the protest of all friends of the Civil Service. The idea was that these veterans should in some way receive some reward at the hands of the Commonwealth, and this was the way selected. It works a great hardship to you as appointing officers, it works a great hardship to the men, and to the women, if you please, who stand high on the list; but that is the law passed by the legislature of this state and is not the doing of the Civil Service Commission, and it is the one thing to-day that causes a great deal of difficulty in the administration of the law.

With that exception there is always leeway, there is always a chance, and there is always a method under the system for trying out the real merits of the system. And when the matter is sifted down, when you look through the records of the last twenty-five years during which Civil Service has been in force in this Commonwealth, when you see the hosts of men and women in all departments of the public service who have come to those departments through the Civil Service system, I think you will agree with me that they have proved themselves pretty capable and efficient servants of the Commonwealth and that they have been able and are and must ever be able to do better their work because they have secured their positions on their own merit and not through any political influence. It leaves them freer

to do their work, and relieves them from worry each time election comes around.

While Civil Service does not directly secure tenure of office, it has the effect of keeping a man in office. If the appointing officer changes, and finds in his new office certain men that he does not know, he is not going to discharge them because he does not know them. He might discharge them if he could put his own friends in, but if he discharges these men he has got to go to the Civil Service list to fill the vacancies, so that in practical operation, and without any law to that effect, the Civil Service system has operated to keep in office men who are found in office by an incoming appointing officer, because there isn't much temptation to remove men who are doing their work efficiently and honestly. The one temptation would be the opportunity to put in a friend or to put in a neighbor, and if that can't be done, experience has shown that people found in office are left there by the new heads of departments. That has been the result all along the line, and I think it will continue to be so.

DISCUSSION.

MR. CARMODY.* I would like to ask if a majority of an outgoing board decides to advance the salaries of employees holding positions under the Civil Service, can those salaries be reduced to their original figure, or must they stand as raised by the outgoing board?

MR. PELLETIER. I will say regarding salaries that, so far as the Civil Service law is concerned, a man can be paid any salary, except in two classes: in the Civil Engineering Department, where there are draftsmen, rodmen, and junior and senior engineers. Before a man's salary can be raised beyond certain limits, he must take the examination for the next higher grade; in clerical positions there are two grades, one which can have a salary up to $800, and the other beyond $800; and to raise the salary in either instance beyond the limit of the class, a noncompetitive examination is given. In the instance the gentleman speaks of, where salaries have been raised, we will assume

* Water Commissioner, Holyoke, Mass.

there is an engineer of the highest grade in the department, there is then no limit under Civil Service for his salary; we have nothing to do with it at all. We will assume his salary is raised $300 a year, and a change comes and the board decides to reduce it $300. The law that I spoke of regarding removals, which I said was not part of the Civil Service law, provides that no person shall be removed from office, or transferred or lowered in grade or compensation without being given a notice in writing assigning the cause and a public hearing, if he so desires. That law would have to be complied with, but, as I said before, that is not a part of the Civil Service system. The same board which reduces the salary says to a man, "You object; come in and we will give you a hearing, and you can show us why your salary should not be reduced." They are the judges, and in the absence of fraud, or something of that kind, I suppose their judgment would be final, although if there were fraud there might be an appeal to the courts. I don't assume to advise on the legal proposition involved there.

Mr. Robert S. Weston.* May I ask how the Civil Service law provides for the very useful class of men who in their earlier years have not had the advantages of education, and yet, who perhaps because of their experience in water works, have become most useful public servants, and far more useful than men who are more literary?

Mr. Pelletier. There is no special provision for that in the law, but, still, there is plenty of room for the general exercise of judgment. For instance, in the Water Department of the city of Boston some few months ago it was discovered that there were some four or five old men who for years and years had been acting as sort of foremen, — men who knew every pipe in the system; when it was put in and how it was put in, — those men, it was found, were acting as foremen, when, as matter of fact, they were only rated as laborers. Several of them could not read nor write. In that case they were given an oral examination and their due rating. Those were cases of old employees in the department. But if you came along to-day, for instance, and said, "I have found a man; he isn't in the department now," — or it

* Sanitary Expert, Boston, Mass.

may be he is in a lowly position, — "I have found this man; I believe he is a jewel, and I would like to appoint him"; we say this: "Before we can give this man an oral examination, or prefer him, we are going to see if in the community, after advertising an examination, we can't get a man just as able who can also read and write." He may not have had the actual experience, but with his general education and ability can't he get his experience later on? If you are going to require absolute experience in every walk in life before you will take a man in, why, of course, we are going to shut business right down all along the line. For instance, a man comes along and says, "You have sent me three clerks. Now none of them have had experience with the names used in the water department. We call valves something else, and we have the most peculiar names for lots of things, and there is a man I know who has been storekeeper here for a long while and knows those names, and he can keep the books because he knows those names and won't have to be asking all the time." We say to that: "Yes, there may be a lot of names, but if we give you a well-educated man, of first-class intelligence, who has passed a high-grade examination, we think he can learn those names in a short while." There is always something to learn. If one of you gentlemen leaves the Boston department and goes to the Lowell department, I will guarantee you will find a lot of things which are done differently there, whether it be in the office or in the larger field, and there will be conditions and things you will have to learn in the new department. That is always so. And so we say, "If we give you somebody of intelligence, won't he soon learn these little routine matters?" But, as I say, we had this case in the city of Boston of the older men, and we gave them an oral examination. While they were pictured as ignorant men, I believe one of them could have passed a written examination. He wasn't nearly as ignorant as he was pictured. That is the only recent case I remember, and that is the way we handled it.

MR. WILLIAM S. JOHNSON.* I am, I believe, like most other men, a firm believer in the Civil Service business when it is applied to the other fellow. My experience has been obtained

* Sanitary and Hydraulic Engineer, Boston, Mass.

in the Engineering Department of the State Board of Health, and there I certainly always had a grievance. The engineers of the State Board of Health were placed under Civil Service and, as has been said, there are three different grades of civil engineers — rodmen, assistant engineers, and senior assistant engineers, I believe. All men who were appointed to the State Board of Health Engineering Department had to pass one of these examinations. These examinations for rodmen, for instance, were very good examinations for rodmen, I presume, but the difficulty was that there is no requirement for rodmen in the State Board of Health, and while the assistants there were civil engineers, they never had to read a rod, or never had to use an instrument. Consequently, while we got men who would undoubtedly make excellent rodmen, they knew nothing whatever about the particular work which was to be done there. It is, I think, one of the great difficulties in the Civil Service, so far as I have seen it, that the classification is not broad enough, there aren't enough grades, and there can't be enough grades to meet all conditions.

Mr. Bond. I should like to ask Mr. Pelletier a question with reference to the Veterans Preference Act. What provision is there for a veteran being dismissed if he is found unsatisfactory or incapable for his office?

Mr. Pelletier. If it is a state position he has a hearing before the State Board of Arbitration; if it is a city position, he has a hearing before the mayor. It is quite different from the provisions of the Removal Act. The discharging officer does not try the case, but the mayor gives a hearing, and it must be public, and the mayor's decision is final. I think those hearings, on account of the importance attached to them and the fact that the chief executive sits as judge, usually take a much wider scope and range than the hearings I have described.

The President. We have a gentleman with us to-day who has not favored us with his presence for several meetings. Those of us who attended the convention in New York in 1905 hold him in very grateful remembrance, and never fail to speak in the highest terms of the entertainment we received when he was a

member of the New York committee on the entertainment of members of the New England Water Works Association. We can never forget what Mr. Smith and Mr. Hazen did for us at the time of the great convention of 1905, which was one of the best that this Association ever had, — I think the very best. I know it would please all the members if we could hear something to-day from Mr. J. Waldo Smith, of New York.

Mr. J. Waldo Smith.* As your President has said, I have only infrequently had the great pleasure of attending your winter meetings. I think every month since December I have made a determined attempt to be here among you, but something has always turned up at the last minute to prevent my coming. I assure you that I regret exceedingly that circumstances have prevented me, except at long intervals, from drawing upon your wisdom. I also wish to assure you that the latch-string is always out in New York. We, in New York, look back upon that week in September, some three or four years ago, as a red-letter week, and we trust that some day the spirit will move you to hold another convention either in or near that city. I am afraid that when you do we will have to get out a new guide book, because New York has changed so much I fear some of you might get lost. In about a year's time from now the Pennsylvania tunnels underneath 32d and 33d streets will be in operation. They are in a very advanced stage of preparation to-day, so that now one can walk from the Hackensack Meadows to Long Island City. The so-called McAdoo tunnels, which run down Sixth Avenue to the neighborhood of Christopher Street, and then over into Jersey, connecting with the various railroad stations, and then back to Courtland Street, are nearly ready for operation; in fact, to-day you can go from 23d Street over to Hoboken in a very few minutes.

The work on the water-supply system, with which I am most familiar, is now at a very interesting stage, and will be more so in a few months. At the present time work has progressed for a year on the Ashokan dam in the Catskills, and about $1 000 000 worth of work has already been completed. The contracts for 50 miles out of 86 to the city limits of aqueduct line are all let

*Chief Engineer, Board of Water Supply, New York City.

or are now being advertised. About 12 miles more will be ready for advertising within a short time, and practically the whole of the aqueduct line contracts will be completed and ready for letting before the end of the present year.

At the Rondout Valley the aqueduct will cross some 400 to 700 feet deep in the rock underneath the surface of the valley. The work on this contract began last June and some of the shafts are now down more than 400 feet. The geological conditions there are much more complex than they are at the Hudson River. There are six or eight different rock formations, that are twisted and crushed so as to make the danger of any inflow of water considerably greater than at the river.

At the point where the aqueduct of the new water supply crosses the Hudson River the distance from shore to shore is about 2 800 feet. I will try to explain as well as I can the shape of the rock profile at this place. On either side a mountain of granite rises from the shore of the river and goes back and up at an angle of about 30°, which represents, approximately, the average slope of these mountains. Borings have already been made in the rock for a distance of about 800 feet from each shore, so there remain only 1 200 feet in the middle of the river where the rock has not been absolutely proven. The reason why it has not been proven there is not the inability to make a boring, but on account of the traffic in the river. Borings that have reached a depth of over 600 feet, requiring a season's work, have at the end of the season been swept away by the very long tows which come down the river. At the present time preparation is being made for making long inclined borings from the shafts, with the expectation of carrying them the full distance to the center of the river from each side. This is not, as you might suppose, an unusual undertaking. In certain regions borings up to 2 500 feet in length have been made, and borings up to 1 500 or 2 000 feet are not considered uncommon. These borings may be kept straight, and may even to some extent be turned at the will of the operator, so that it is possible to carry the holes on a known slope for 1 000 feet or more and then by manipulation to change the angle. I do not know that it is possible to turn them downward, as the natural inclination of a boring of this kind is

toward a flatter slope rather than to a steeper one. But anyway, I personally, and I can speak for the engineering staff on the work, feel that the crossing of the river is not only practicable, but is an absolute certainty. I hope that when this Association does come to New York again the members will have an opportunity to see some of this work, and perhaps some day even walk underneath the Hudson River.

I have been very much interested in the remarks by Mr. Pelletier on the Civil Service question in Massachusetts, and I cannot miss an opportunity to give my testimony that to any man occupying an executive position on public work the Civil Service is a true blessing. I believe that where it fails it fails more because of the spirit in which it is carried out by the heads of departments and others than from any defects in the system itself. Most of my life has been spent serving corporations where the privilege of selecting one's assistants was absolute. For the last few years I have had opportunity to select men entirely from the Civil Service. And I am bound to confess that the men selected through the Civil Service Commissioners are fully the equal of any of those who have ever served me for public corporations. To do this it has been necessary to exercise every privilege which is possible under the Civil Service law and rules; and I believe it is imperative on every officer who has the appointment of men to exercise these privileges, and if they are exercised faithfully I believe that a most efficient force may be secured through the Civil Service, and that the force is more likely to be maintained.

PROCEEDINGS.

MARCH MEETING.

HOTEL BRUNSWICK,
BOSTON, MASS., March 10, 1909.

President Thomas in the chair.

The following members and guests were present:

MEMBERS.

S. A. Agnew, L. M. Bancroft, F. A. Barbour, H. K. Barrows, A. F. Ballou, G. W. Batchelder, J. E. Beals, J. F. Bigelow, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, James Burnie, W. L. Butcher, T. J. Carmody, F. H. Carter, J. C. Chase, C. E. Childs, H. W. Clark, J. H. Child, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, R. J. Crowley, G. W. Cutting, Jr., John Doyle, M. J. Doyle, E. D. Eldridge, A. D. Fuller, F. L. Fuller, F. J. Gifford, Albert S. Glover, F. W. Gow, C. W. Gilbert, F. H. Gunther, F. E. Hall, J. O. Hall, T. G. Hazard, Jr., D. A. Heffernan, M. F. Hicks, K. H. Hyde, R. K. Hale, W. R. Hill, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, C. F. Knowlton, J. J. Kirkpatrick, S. H. McKenzie, N. A. McMillen, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, G. F. Merrill, C. A. Mixer, William Naylor, F. L. Northrop, T. A. Peirce, A. E. Pickup, Dwight Porter, P. R. Sanders, E. M. Shedd, C. W. Sherman, J. Waldo Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, T. V. Sullivan, C. F. Story, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, L. D. Thorpe, J. L. Tighe, W. H. Vaughn, C. K. Walker, R. S. Weston, F. B. Wilkins, G. E. Winslow. — 87.

ASSOCIATES.

Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by Harold L. Bond; Builders Iron Foundry Company, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edward F. Hughes; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; F. H. Hayes Machinery Company, by F. H. Hayes; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; Neptune Meter Company,

by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. M. Barnard; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. W. Van Winkle and H. F. Quint. — 25.

Guests.

Fred O. Eaton, Portland, Me.; Daniel MacDonald, superintendent Water Works, Middletown, Conn.; Sam'l F. Crompton, mechanical engineer, East Greenwich, R. I.; M. S. Kahurl, Fred A. Houdlette, Hon. Joseph Pelletier, T. A. Collins, F. E. Davis and William E. Hannan, water commissioner, Boston, Mass.; Jesse E. Sheldon, water commissioner, Holyoke, Mass.; J. H. Garratt, Cambridge, Mass.; J. B. Coughlin, Lowell, Mass.; L. B. Lynch, Milford, N. H. — 13.

Before the regular business of the meeting was begun Mr. James Coughlin, of Lowell, who was present as a guest of Mr. William F. Sullivan, the superintendent of Pennichuck water works of Nashua, N. H., having been called upon by the President, gave two recitations, which were much appreciated and loudly applauded.

The Secretary read the following names of applicants for membership, their applications having been properly endorsed and recommended by the Executive Committee:

Daniel MacDonald, Middletown, Conn., superintendent Water Works; John T. Sharp, Jr., Canton, Miss., superintendent Canton Light and Water Works; Frank Chappell, Montreal, P. Q., civil engineer and student at McGill University, Montreal, in municipal engineering; Robert H. Brown, New York, N. Y., civil engineer, engaged in the construction of water purification and sewage disposal works; Bradley M. Lockwood, Franklin, Mass., chairman Board of Water and Sewer Commissioners; Edward Barton, University of Illinois, Urbana, Ill., teacher of chemistry and director of State Water Survey of Illinois; Jesse E. Sheldon, Holyoke, Mass., water commissioner. For associate membership, the Darling Pump and Manufacturing Company (Limited), Williamsport, Penn.

On motion of Mr. Coggeshall the Secretary was empowered to cast the vote of the Association in favor of the applicants, which he did and they were declared elected.

The Hon. Joseph C. Pelletier, of the Massachusetts Civil Service Commission, was present and spoke on the subject of "Civil Service in Its Application to the Water Department." Mr. Carmody, water commissioner of Holyoke, Mr. Robert S. Weston, Mr. William S. Johnson, Mr. Bond, and Mr. Waldo Smith took part in the discussion which followed the address.

Mr. Carroll F. Story, civil engineer, Springfield, Mass., presented a paper on "The Ludlow Filters." Mr. Robert S. Weston, William S. Johnson, A. E. Martin, Harry W. Clark, Frank L. Fuller, and Mr. G. S. Snell, of Attleboro, spoke.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., March 10, 1909, at 11.30 A.M.

Present: President Robert J. Thomas and members George W. Batchelder, William F. Sullivan, George A. Stacy, George A. King, Frank L. Fuller, Edmund W. Kent, Lewis M. Bancroft, Richard K. Hale, Charles W. Sherman, and Willard Kent.

Applications for active membership were received from Daniel MacDonald, superintendent water works, Middletown, Conn.; Bradley M. Rockwood, chairman Board of Water and Sewer Commissioners, Franklin, Mass.; Jesse E. Sheldon, water commissioner, Holyoke, Mass.; Robert H. Brown, civil engineer, New York City; Edward Barton, director of the State Water Survey of Illinois, Urbana, Ill.; John T. Sharp, Jr., superintendent Canton Light and Water Works, Canton, Miss.; Frank Chappell, civil engineer, Montreal, Canada, and for associate membership, the Darling Pump and Manufacturing Company (Limited), Williamsport, Penn., and by vote they were unanimously recommended for membership.

On motion of Mr. Batchelder, seconded by Mr. Bancroft, it was voted that an informal ballot be taken for an expression of opinion in regard to place of holding the next annual convention.

The ballot was followed by the appointment of a committee of five, consisting of the President, Secretary, Ermon M. Peck, George A. King, and George W. Batchelder, to investigate and report on the respective merits of the cities of Bangor, New Haven, and New York.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Tremont Temple, Boston, Mass., May 13, 1909.

Present: President Robert J. Thomas and members L. M. Bancroft, Ermon M. Peck, George W. Batchelder, Charles W. Sherman, Edmund W. Kent, George A. Stacy, George A. King, Richard K. Hale, and Willard Kent.

On motion of Mr. Peck, seconded by Mr. Sherman, it was voted: That the next annual convention of the New England Water Works Association be held in the city of New York.

On motion of Mr. Batchelder, seconded by Mr. King, it was voted: That the date of the next annual convention be September 8, 9, and 10, 1909.

On motion of Mr. Sherman, seconded by Mr. King, Mr. Batchelder, the President, and Secretary were made a committee to make all necessary arrangements for the annual convention.

The date of the June outing was made Wednesday, June 23, subject to its being possible to make arrangements for that date, the committee already appointed (Mr. Sherman, Mr. Hale, and Mr. Maybury) being continued with full power to make all necessary arrangements therefor.

Voted: That the invitation of the Boston Society of Civil Engineers to join them in an excursion to Springfield be accepted.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

F. A. W. Davis, president and treasurer of the Indianapolis Water Company, died of pneumonia at Pelham, New York, on Friday, April 9, 1909.

Mr. Davis was born September 24, 1836, at Jackson, Mo., and first came to Indianapolis in 1852 to seek employment. He was first employed as a clerk in one of the prominent stores, but later entered a bank where he was employed in various capacities for quite a number of years. During the Civil War, as officer of one of the banks, he handled all of the money with which the Indiana soldiers were paid.

From 1865–1881 he was cashier of the Indiana Banking Company, when, through his relation with the bank, he became vice-president and treasurer of the Indianapolis Water Company. He continued in this capacity until 1904, when he became president and treasurer of the Water Company, which position he held until his death. He is survived by a wife and two children.

Mr. Davis was an ex-president of the American Water Works Association and a member of the National Conservation Commission, the Lakes-to-the-Gulf Deep Waterway Association, and the Indiana Engineering Society. He was elected a member of the New England Water Works Association on June 17, 1887.

NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE LUDLOW FILTERS.

BY CARROLL F. STORY. CIVIL ENGINEER, SPRINGFIELD, MASS.

ERRATUM.

1909 JUNE JOURNAL, VOL. XXIII, NO. 2.

Page 147, fourth line, read "an easement" instead of "the fee."

lower than certain new parts of the city. It became necessary, immediately, to look for a new supply, both because the old was inadequate and because it could not be made to serve the entire city. There are several tributaries of the Connecticut River which are located within a radius of fifteen miles of Springfield, at an elevation sufficient to supply the city, and studies were made of different supplies which were available. It is interesting to know in this connection that the Westfield Little River was finally selected, but a more careful study of the cost proved that it could not be taken by the city as a cost of $1 000 000 was considered prohibitive for a city of 26 000 people. Further studies were made, and finally Mr. George Raymond, of Fitchburg, Mass., who had

been called in for consultation in the matter, recommended that certain branches of the Chicopee River lying from twelve to sixteen miles northeast of Springfield could be taken at a cost which would be within the city's means. A large storage could be obtained by building two dams, and the supply could be brought into the city by a cement-lined pipe line. The report started a bitter controversy, and one member of the commission resigned because he thought that the policy was unwise. Two parties were thereby formed which have existed almost to the present date. Some people have thought that the Ludlow water could be made usable and that everything possible should be done for its improvement rather than to go to the expense of taking other water for the city. The other party has always maintained that a mistake had been made in selecting the Ludlow water, and that the best way out of it would be to turn to an entirely new supply. The two parties were finally unified, however, in a policy which will be outlined during the course of this paper.

The storage which was obtained in Ludlow reservoir was secured by building two dams which flooded what was then known as Dark Island Swamp. A capacity of 1 800 million gallons was obtained with a flowage of about 430 acres and an average depth of slightly over 10 feet. Later investigations which will be mentioned later in greater detail have disclosed that it was almost a bottomless swamp, the black muck varying in depth from one foot to forty-six and a half feet, the average depth of mud being in excess of five feet. The shores of the reservoir have numerous small coves which are well protected from the wind and in which the water is very shallow. Any one conversant with water supplies will recognize that the large storage in Ludlow reservoir was obtained under the most disadvantageous conditions possible. It is hardly to be wondered at that trouble has been experienced from the first with microscopical organisms.

The first year that the reservoir was filled, a troublesome growth made the water almost undrinkable. This was undoubtedly due to anabaena. It is interesting to note the records which were kept by the gatekeeper during the succeeding years. The water was unfit to drink at some time or other during practically every summer. The conditions were so bad that about 1890 it was

decided to double the size of the watershed in the hope that the additional circulation which would come from the large amounts of fresh brook water would help conditions materially. The city was also nearing the time when a larger supply was needed. Accordingly, Jabish Brook was diverted and brought to the reservoir by a long canal. It is generally conceded that some improvement was noticeable, but this was not lasting in character. Two pumping stations were accordingly added on small ponds located along the pipe line between the reservoir and the city. These ponds had no inlets and were in reality merely a storage of ground water of a very satisfactory quality. During the bad period of the summer this water was used to supply the deficiency in amount of fresh brook water, which was diverted around the reservoir directly into the mains. This necessitated the use of unstored brook water and was dangerous, although inspection of the watershed was maintained.

Finally, in 1900, the reservoir was drained with the idea that stripping off the muck which constituted its bottom would better the conditions. A survey of the reservoir was made and soundings were taken to ascertain the amount of stripping necessary. When it was found that the muck extended to a depth of from thirty to forty feet in places, with a maximum of forty-six and a half feet, the idea was given up. Mr. Percy M. Blake, civil engineer, was called into consultation, and a series of filters were operated, in connection with the State Board of Health, to see just what might be done in the way of filtration. The results of a year's run are fully covered in the State Board of Health's report of 1901. It was found that the water could be satisfactorily filtered for almost the entire year, but that there was a period in the case of each filter when the water could not be handled. Mr. Blake reported unqualifiedly against filtration and recommended that the Ludlow supply be abandoned as soon as a new supply could be obtained. He recommended that the north branch of the Westfield River be taken. The State Board of Health approved his report.

Permission was asked of the state legislature to divert the waters of the river which Mr. Blake had recommended. Permission was, however, denied, due largely to the fact that the city was not unanimous in feeling that this was the wisest course.

This action forced the city to go into the problem anew, and Messrs. Samuel M. Gray, civil engineer, and George W. Fuller, civil engineer, were retained in 1903 by a special commission to look up the matter again. Under the personal direction of Mr. E. E. Lochridge, now chief engineer of the Springfield Water Department, a series of twelve filters were run during the summer months. It was found that filtration, while possible, would not be advisable. The engineers recommended that the supply be abandoned and that permission be again asked of the legislature for the north branch of the Westfield River. They did not feel that the expense of double filtration and triple aëration, which they deemed necessary for a satisfactory purification of the water, would be justifiable for Springfield, inasmuch as the supply was inadequate and would have to be extended at an early date.

In the spring of 1904 the city council appropriated $300 000 for the filtration of Ludlow water, and Mr. Allen Hazen, civil engineer, of the firm Hazen & Whipple, was retained by the city to prepare plans for the plant. He studied the situation and the previous experiments, and he reported that he thought that a filter of the kind intended would fail at times to purify the water without preliminary treatment. The loss of head necessary for filtration would reduce the pressure in the city to a point which would render the fire protection inadequate. In view of the fact that it was necessary to extend the supply, and as the extension of the Ludlow supply would involve large expense, he deemed the best action possible would be to abandon the supply and to take water from the Westfield Little River.

The feeling at this time was bitter. Many thought it impossible to secure any grant from the legislature and considered that it would be necessary to extend the present supply. A compromise plan was suggested. It was decided to do as much as possible for Ludlow at a reasonable cost and to unite and try once more to secure the permission of the state legislature for a new supply. Mr. Hazen felt that a rough filter could be built for a reasonable amount which would help the bad water in the summer very materially. Accordingly, in 1905, $75 000 was voted by the city council for the construction of a temporary filter to be designed by Mr. Hazen, and a unanimous vote was passed petitioning for the

new supply from the Westfield Little River. An epidemic of typhoid which had been prevalent during the summer, although not attributable to the water supply, awakened the people to the dangers of using unstored brook water along with the water of the three emergency ponds, the third one having been added for that summer's use.

This history of the Ludlow supply will reveal the reasons for the construction of a filter of the type which was finally built. Its use was to be only temporary. The cost, while large, was still small enough so that the full value of the filter would be realized in the few years in which its use would be necessary. Conditions were ideal for the construction of such a filter. Two arms of the reservoir were divided by a long point composed almost entirely of a sand satisfactory for filtration. One of these arms had been closed off from the main reservoir by a dike and was used during the summer months for the storage of the fresh brook water. During the winter the gate on a 36-inch main connecting it with the reservoir proper was opened and the two stood at the same height. This basin was to be used for the storage of filtered water. By leveling off the point, an area of four acres could be obtained for filtration. The amount of pumping necessary would be a minimum, as the water could be raised from the reservoir on to the filters, flowing down through the sand into the system of underdrains and out into the basin. No pressure would thus be lost in the city.

This was the only type of filter that could be built quickly enough to be of service for the coming summer season. Plans were hurried and the contract was let in the fall of 1905 for the leveling off of the peninsula so that the work would be finished by spring in time for the construction of the filter proper which was to go upon this area. No concrete floor or special precaution of any kind against the loss of water was used. Upon the surface thus leveled, and which was fairly compact, due to the fact that the filling had been done into a depth of from three to fourteen feet of water and had been subject to the freezing and thawing of the winter weather followed by spring, the tile underdrains were laid with open joints. These underdrains were 6 inches in size for a part of the length, and 8 inches for the rest. Three-quarter inch openings were left every

2 feet, and the lines of tile were 12½ feet apart. These underdrains all came into the central drain, which was of concrete, at a point several feet above the level of the water which would exist in the drain during the operation of the filters. The central drain divided the filters into two sections, two one-acre beds being on each side. Above the underdrains were laid layers of gravel which was washed from the bank sand. This was the only washing and screening which was done for the building of the filters. On top of the gravel was spread 5 feet of sand from the bank, the sand being placed in the filters after an analysis of each carload, the aim being to keep the effective size above .30 millimeter.

Excavation was carried on by means of a steam clam-shell bucket which loaded a train of ten cars, each holding three and one-half cubic yards. As soon as a train load was filled the different cars were analyzed. If the sand in any car was found unsuitable, it was placed in the embankments; otherwise it was used in the filters. Filling was done by keeping the track at the edge of the fill so that the sand was dumped into its proper place without a second handling, and the final grade was secured at once.

In the center of the four beds was located the aërator, which is one of the novel and essential features of the plant as constructed. The end of the 30-inch pipe from the pump discharges into a basin or aërator 30 feet in diameter built of concrete. Surrounding this basin is a concrete apron and an area paved with large stones so that the entire diameter of the aërating system is 60 feet. The aërator is so arranged that the water can be discharged into any combination of the four beds that may be desired. It is customary in operation to use three out of the four beds, leaving the other out to be cleaned. The beds are cleaned in rotation. The capacity of the pump is sufficient so that sixteen hours supplies the amount of water necessary, the operation thus becoming intermittent as with a sewage filter.

The essential features of filtration are the central aërator, the intermittent operation of the filters themselves, and the aëration which follows the filtration by the water falling from the small drains into the large drain, which is 56 inches high and 30 inches wide, inside dimensions, and from the wooden flume which leads from the large drain into the water of the basin below. The aëra-

tion and intermittent action of the filters are undoubtedly the two features which lead to the successful filtration of Ludlow water. In the experiments of the State Board of Health it was found, during the worst periods, that filters which ran at a high rate allowed anabaena to pass through them, and that those which worked at a low rate were utterly unable to take care of the water, as there was so little oxygen present during the bad stages of the reservoir water that it was entirely removed during the process of filtration. A water resulted that was utterly unfit for use.

With this account of the conditions, and this brief outline of the design, I shall pass into the operation itself. It has always seemed to me that the most interesting account possible would consist in a relation of experiences. The analysis of the different years' operation is given in the reports of the Board of Water Commissioners, so that any one interested in the purely technical side of filtration can study out just what the filter has done in the way of improving the water during the past three seasons.

The filter was put into operation early in July, 1906, under the direction of Mr. George H. Shaw, and the results were very satisfactory for the summer. At no time during the year was there present in the reservoir the amount of anabaena that was usually found in previous seasons; the summer's run, therefore, failed to furnish a good idea of just what might be expected.

In May, 1907, I was sent out to take charge of the filters for the season. I found the work of resurfacing the beds had been started some days previous and that two out of the four beds had been brought back to grade. It was thought by those connected with the department that resurfacing could be done in a filter of this kind without any undue danger of sub-surface clogging. All dirty sand was removed from the top and a layer of new sand was placed deep enough to bring the filters back to their original grade. Due to the heavy scrapings which are necessary in a filter of this kind, and to the fact that considerable settlement had taken place in some sections of the beds, this layer varied in thickness from six to fourteen inches. It was thought that the layer was thick enough to provide against the dangers of the dirt going through, and the precaution was not taken to mix the new sand into the old by spading. We learned better by experience, however.

About the first of June, when three of the beds had been brought to grade, and the other had been almost finished, it was decided to start up the filters, although the water in the reservoir was still pretty good. This was done to give the filter a chance to get to working in good shape before bad water would come. The filters were started on a Wednesday, and by Friday night all four beds were filled to the top and were barely taking care of the amount of water thrown by the pump. I saw that some action would have to be taken the following morning and ordered the men to report early. Upon going out on the filters the next morning I found that three of the four beds still had water on them, although it was eight hours since the pump had ceased to work. The odor about the beds was so strongly fishy as to be oppressive, and the men complained of it a number of times during the morning. Getting all the boots that I could in the neighborhood, I put the men on to the filters in order to rake the water down. Then the beds were allowed to stand in the sun and bake until they had dried out thoroughly. They were then given a good raking and the pump was started up. They worked better after this treatment, but I saw that it would be necessary to start at once on the work of scraping, although the filters had been in operation only four days.

To say that I was discouraged at the outlook would be putting it mildly. I had been sent to the filters under orders not to rake the beds under any condition, because the State Board of Health had not had very good luck with this form of treatment, and here at the very start I found that I was forced to resort to it. I went into the laboratory after the filters were running to make a microscopical analysis of the water and found that it contained a large amount of uroglena and asterionella. For the next three weeks the water continued to be almost as bad, the numbers of asterionella varying from about two thousand to seventy-one hundred standard units per cubic centimeter. Operation grew less difficult as the asterionella gradually disappeared. In this connection I may say that my experience with asterionella has not been a pleasant one. The filters will remove the taste and odor very satisfactorily, but the organism seems to completely cement the top layer of the sand so that no water is able to pass through. I have removed solid chunks of sand six inches square and half an inch

thick which were cemented hard enough so that they still held together weeks afterwards on the shelf of the laboratory. Raking seems to be the only treatment which will keep the beds going during this trouble. I found that a raking which followed a thorough drying out of the bed in the sunlight was fully as satisfactory as scraping off the dirty sand, both as to the quality of the water and as to the ease with which it passed through the sand.

There was very little anabaena present during the first two weeks, but the organism multiplied rapidly during the last part of June. The filters stepped from an epidemic of asterionella right into one of anabaena, but we were fortunate enough to have them working well by that time. The water was very dirty indeed, but the period of the filters was not very short. The anabaena epidemic culminated on the 3d of July with a count of over twelve thousand standard units per cubic centimeter. On that date the color of the water was almost doubled, iron jumped from .5 part per million to over 1. part per million, CO_2 disappeared entirely from the reservoir water, and dissolved oxygen dropped to a much lower figure. This will give some idea of how extreme the fermentation was. The weather had been still and hot for a week and conditions were just right for the fermentation which took place. Filtration on the day in question was difficult, due to the large amount of organic matter in the water, a bed that had just been cleaned filling to the top. Matters eased up considerably the following day, although the effect of fermentation was still apparent. It was several days before CO_2 was again present in the reservoir, and the dissolved oxygen dropped to a low figure, where it remained for the rest of the month. Many dead fish were found about the reservoir during this period. Anabaena died out rapidly and had disappeared quite largely in three days. The numbers which had been present for the two weeks preceding had averaged well in excess of twenty-five hundred standard units per cubic centimeter.

The water during the epidemic of anabaena, strange as it may seem, is much easier to handle than the water afterwards. Reservoir water which had been undrinkable on a number of days was filtered so satisfactorily that it contained almost no taste and odor

perceptible even to an analyst, when it dropped from the end of the effluent flume. It was much improved in all respects chemically; half of the color, almost all of the iron, and a large part of the ammonia being removed. But after an epidemic has ceased and the water is full of the oil, which is present during the life of the organism, and of organic matter, due to the death of the organisms, operation becomes more difficult. The taste and odor, although well removed, are not removed quite as completely as during the other stage. It is necessary to give the plant much closer attention in order to secure good water. The period of the bed becomes much shorter and the dirty layer on top is both thicker and blacker. If scrapings are made frequently enough filtration will be very satisfactory. If this is not done the rate of filtration becomes slower and the same conditions will tend to manifest themselves that the State Board of Health found. Slow filtration during this period means a large removal of oxygen and a much poorer water. I watched conditions very closely and always tried to secure a water from the underdrains before the afteraëration which would be high in oxygen. If I found a bed was giving a water low in oxygen, I hurried up the scrapings so as to clean this bed as quickly as possible. By taking this precaution, I was successful in obtaining a water that was always practically free from taste and odor.

About the middle of July the filters began to work very poorly from a mechanical standpoint. The filtered water continued to be good, however. Although the beds were not dirty, it seemed to be hard to get water through them, and we began to hunt for the cause. Mr. Lochridge thought that it was due to the fact that the furrows which we had made in the beds to facilitate the distribution of water and to keep the beds from becoming air bound had pretty well disappeared. He was under the impression, in fact, that the beds were air bound. I started the work on one of them of enlarging the furrows, and in doing so discovered the true state of affairs. Beneath the new sand which we had placed in the spring was a thick dirty layer of sand at the top of the old bed. This was due to the dirt which had gone through the new sand. The beds were in pretty bad shape, due to this sub-surface clogging. I gave the filter which I was then cleaning a thorough overhauling,

removing all of the new sand where it was not very deep and the dirty layer on top of the old. In places where the new sand was deep, I removed as much of it as I could by shoveling the sand to one side and taking the dirt out. I then refurrowed the bed and spaded the new sand thoroughly into the old at all points where I had been able to remove the sub-surface dirt. The bed worked much better after this treatment and I gave each one of the other three the same treatment when I came to it on the regular round of scrapings. It was impossible, however, to remove all of the sub-surface dirt, as there was not time to go beneath the thickest portions of new sand. At the end of the year, however, all of the sand placed at the beginning of the year was removed. After this treatment the filters worked easily, giving at all times a water that was fully as satisfactory as any one could wish for.

During August and September the reservoir became very low. There were several minor fermentations of the water with their attendant increase in color and in iron and the accompanying loss of dissolved oxygen. During these times the number of anabaena would rise to several thousand standard units per centimeter for a day or two and would then drop back to a value in the hundreds. Filtration in each case was a little more difficult for several days, but conditions would then go back to the normal. Due to the thorough fermentation which the water had had, filtration was very active and the removal of color, iron, and ammonia was very high. It may be of interest to state in this connection that during July, August, and most of September, an average of over fifty per cent. of color removal was obtained. This was in contrast with the twenty-five to thirty per cent. that may be expected from an ordinary filter receiving fresh brook or river water of the kind that we have in New England.

Toward the latter end of September the character of the water changed materially. The fall was a very wet one and the reservoir filled rapidly to the high-water mark. The result of the fresh water was apparent immediately, as much less color was removed by filtration. Operation during the fall was more or less difficult, at all times due to the character of the water and to the frequent heavy rains. There was a distinct epidemic of coelosphaerium, which lasted throughout the entire fall, there being present at

times as high as six and seven hundred colonies in a cubic centimeter of reservoir water. The odor of the water was very grassy and quite disagreeable, but the filtered water throughout was of a satisfactory quality.

I have mentioned the fact that rains made operation difficult, but it may not appear quite clear why this should be so without further explanation. A hard rain coming on a bed which was being cleaned seemed to float the dirt from the windrows and cover over the entire surface with a very black layer. It became necessary to scrape a part of the bed the second time as it seemed to be impossible to get water through without this work. In addition to the redirtying of a bed, there was also a hardening action and the top layer of sand was sometimes so hard that it was impossible to make much of an impression on it with your heel. It was so hard, in fact, that a heavy iron rake used with all of a man's strength failed utterly to break up the top. After one or two experiences of this kind, I watched the weather pretty closely and tried not to have a bed off for cleaning at a time when rain seemed likely. I sometimes had the men work until dark in order to finish a bed so that I could turn water on to it before a rain storm came. There was a further difficulty in that it was impossible to work about three days out of every seven. Coupling this with the dirty water and with the bad effect which the rain had on the beds themselves whenever they happened to be caught off, the mechanical operation of the plant was anything but easy. A covered filter, of course, would have done away with most of this difficulty, but in such a temporary plant we had to get along as best we could. By using a large gang of men and doing considerable raking to tide over some of the rainy spells, it was possible to keep things going.

The filter was finally closed down about Thanksgiving time as the reservoir water by that time was satisfactory enough without filtration. The people, however, had become so well educated to the filtered water that they noticed the difference at once. The color was so much higher that we received a good many requests to keep the filter operating longer. In the earlier days, the citizens would have considered that they were receiving a very satisfactory water.

Altogether the summer may be considered to have been a good test of what the filter might be expected to do. A reservoir water that had been at almost all times bad enough to have rendered it more or less unfit for use had been changed without exception to one that was practically without taste and odor when delivered to the consumer. In addition to this, its appearance was almost colorless and it was always entirely free from sediment of any kind. The large improvement in the color was due, as I have said before, to the character of the water itself, part of the removal being vegetable stain in the water and the rest iron.

After pumping had ceased, the beds were all thoroughly scraped by removing the stained sand from the top. The scraping was heavy in places, due to the fact that there was still some sub-surface clogging left which we had been unable to remove during the regular scrapings, and this was entirely removed. Owing to the experience which we had had in this connection, it was decided to put no more clean sand on the beds during the rest of the time that the filters would be used, as they had originally been constructed with five feet of sand and not more than three feet is really necessary. But two more seasons were left for the filters before the Little River supply would be finished and there was enough sand left to finish out this period.

Early in the spring of 1908 the reservoir water became rather disagreeable, due to the presence, as we found, of dinobryon, and we received numerous requests expressed in the newspapers and by telephone that the filters be started for the season. As there was still considerable frost in the ground this was impossible, but we decided to start the filters somewhat earlier than they had been put into operation the year before. This decision was made partly with the desire of getting started before bad water should come, and partly because it was thought best to give the people the benefit of the improved water as long as possible.

A start was made on filtration about the middle of May, but we were again unlucky enough to run into asterionella almost the first thing. The experience of the year before was exactly repeated. At the end of two or three days' run the filters were all full and it became necessary to resort to raking. Operation was difficult, but with the experience which we had gained the year before it was

much easier to keep things going nicely. I adopted a regular system of raking the beds and in this way succeeded in running the plant with much less worry and trouble than was possible the preceding season. The number of asterionella per cubic centimeter ran well into the thousands for several weeks, with a maximum of 7 200, and the organisms did not entirely disappear until the middle of June.

After the disappearance of asterionella the filters ran better probably than they had for any other period during the preceding seasons. For most of June and a part of July so little work on the beds was necessary that it was hard to find enough to do to keep the men busy, although during a part of the time there was considerable anabaena in the reservoir water. The epidemic was not of as long duration as was the one of the preceding season and was not as severe.

Later in the summer coelosphaerium again put in its appearance, although not in very high numbers. The water was fairly dirty, but pretty easily handled, and the filters went without very much attention other than an occasional scraping until about the first of September. During this time the reservoir was steadily dropping and the experience of the preceding summer in the removal of color and iron was repeated. The filters were, if anything, even more efficient, and an average of over 55 per cent. of color removal was obtained for the months of July, August, September, and October.

Owing to a continuation of the long dry spell which made the past year famous, the reservoir dropped steadily throughout the rest of the year. During the latter part of September, all of October, and the first part of November operation of the filters was more or less difficult. This was due probably to a combination of causes. The water in the reservoir was as dirty as it had been at any time for several years. Anabaena, cœlosphærium, and asterionella were all present in rather large quantities and the water had a disagreeable taste and odor. The second factor was the low stage of the reservoir. The pump that supplies the filters is a centrifugal pump of 20 000 000 gallons capacity in twenty-four hours and is supplied by water through a 36-inch suction from the reservoir. When the filters were built the suction had been ex-

tended into as deep water as could be secured without going to a great deal of trouble and expense. The water became so low that it was necessary to float a large platform over the end of the suction to keep down the swirl which resulted from pumping. This platform seemed to throttle down the discharge of the pump to a considerable degree and it became necessary to pump twenty and twenty-one hours a day to get the amount of water needed for the city. Without the platform it would have been impossible to have operated the pump at so low a stage, as air entering through the swirl would have caused the pump to drop its water. The long hours of pumping destroyed to a certain extent the intermittent action of the beds, as a filter unless fairly clean would fail to uncover in the four hours which the pump was shut down. This fact rendered raking difficult, as too much time was lost in raking down the water to allow the bed to dry out properly. Even with a large force of men the beds became very dirty during the last part of the period. Notwithstanding the severe conditions under which the filters were operating, the water at all times was of a good quality, probably as good as had been secured during the rest of the year.

Finally, early in November, the reservoir reached the stage below which it was impossible to operate the pump any longer. The platform rested on the top of the intake box and there was less than eighteen inches of water over the top of the pipe. Several times during the last few hours of pumping the pump started to race and the engineer expected every time that he would have to close down. It was thought best to take no further chances and the pump was accordingly shut down.

The effect of stopping the filters was noticed very quickly in the city and complaint was very generally made as to the quality of the water. The water was really extremely objectionable and dealers in spring water did a thriving business until the coming of cold weather. The people were told that the water was no worse than that which they had used in a good many preceding years, but it was hard to make any one believe the statement. The use of good water for three years had educated the people of Springfield to the advantage of a good supply, and satisfaction is generally felt in the city that the completion of the Little River supply is near

at hand. Even the most bitter opponents of Little River have finally given in and now seem to feel that the city was wise in looking for a new supply.

Now that I have covered in a general way the experience which we have had during several seasons, I will describe the process of raking and scraping. After a bed had been in use for a few days it is shut off at night and left off the following morning, until it has thoroughly dried in the sun. Then the men are sent on to it with heavy long pointed iron garden rakes, and they give the top a thorough raking. This breaks up the coating into a fine powder and opens the pores of the sand. A bed thus treated delivers as satisfactory a water as a bed which has just been cleaned, and works about as well. The dirt in the water does not seem to penetrate very much deeper on account of this treatment, but it does make the scrapings somewhat heavier, and I was always careful not to use this method too frequently. During the period that anabaena was in the water I used it very little as I always kept in mind the experience of the State Board of Health. It was extremely efficient, however, during the time that asterionella was prevalent, and during periods in which there were few organisms in the water I tried not to have more than one or two rakings before scraping, but during the first fall when we had so much rain this was not always possible. The scrapings then became very heavy and the cost of operation may have been even increased by this process. It could not be helped, however, and the running of the beds at all during that time was probably due to raking.

The process of scraping is different from that in use in other places, in that a hoe is used instead of a wide shovel. The use of a shovel was found impracticable on account of the large number of stones in the sand. A much thinner layer is removed and the work is done more easily with the hoe than with the shovel. The dirty sand is collected in long rows and is wheeled from the beds by wheelbarrows, being wasted over the bank into the reservoir. It will be easy to understand that this method of scraping is much more costly than in a filter where there are mechanical devices for moving the dirty sand. This is the only method justifiable in a plant of this kind where it was desired to purify the water as fully as possible with a small outlay of money. I have always con-

sidered the plant a very wise expenditure of a little over $50 000. After the scraping is completed the surface of the bed is very thoroughly raked and smoothed over with heavy rakes. This raking is more thorough and is much harder than that given to a bed between the period of scrapings.

It is a little hard to say just what the period of a bed is as the time varies so greatly with the quality of the water. I have seen a bed operate for almost three weeks without even a raking. On the other hand, at the end of four days scraping has been necessary. These are probably about the two extremes, and ordinarily they will run about ten days between scrapings, with a raking in the middle of this period.

With the three years of operation of the Ludlow filter it is possible to get something on the cost per million gallons furnished to the city. The consumption data is a little uncertain, but we have used for a basis figures which we obtained several times by loss from the clear water basin when the filter was shut down for twenty-four hours. These agree very closely with what the consumption of the city has been estimated in other ways. The average figure for three years shows a cost of $5.73 per million gallons of water delivered to the city, exclusive of interest and depreciation on the investment. As the entire construction cost of the four acres of filters was $50 723.94, the interest on this amount does not add materially to the figure. It is a little hard to tell just what depreciation should be figured, as the plant is only a temporary one. When the filters are brought back to grade the plant will be practically as good as new. This will probably be done as the supply is to be held against possible use in the future. After the cost of this work is known, more reliable figures can be obtained. Even if the plant should be considered wiped out at the end of four years it would not bring the cost of filtration per million gallons very much in excess of that of some other places, and if a reasonable rate of depreciation is taken the cost will compare very favorably with that of other filters. At any rate, the investment has certainly been a very wise one.

DISCUSSION.

Mr. William S. Johnson.* I would like to ask if any more trouble than usual was experienced, after the filtered water was introduced, from a coating of organic matter becoming attached to the inside of the pipe?

Mr. Story. As far as we have ever been able to find out there has not been any trouble. The water has always been free from sediment and low in color. We have noticed one effect of the filtered water, and that is the difference in iron. On following down the pipe line, taking samples at different points, we have found that the filtered water takes up iron as it goes through the pipe, but by the time it has reached the city it begins to drop it again, so that there is an action of that kind on the inside of the pipes.

Mr. J. Waldo Smith.† I would like to ask about the efficiency of the aëration in improving the water as it comes from the reservoir before it is introduced on to the beds.

Mr. Story. In that connection, I may say that during the entire summer we measured the dissolved oxygen in the reservoir water, and during the worst periods the per cent. of saturation has dropped down, as I remember it, to about 35 per cent. Even during those periods the filtered water taken from the small drains would have a saturation of from 80 to 90 per cent., depending upon just how clean the bed was. A bed which had just been put on would run about 90 per cent., and as it grew dirty it would approach the condition which the State Board of Health found. If the water went through slowly, too much oxygen was removed. I always tried to watch the water in the small drains, and if the saturation dropped below a point of about 75 per cent. I would hurry up scraping and get that bed off as quickly as I could, for I was afraid that there might be a period when the water would not be good. I found, however, that that limit was always on the safe side.

Mr. Smith. Was there any effect on the organisms as the result of aëration, either removing them from the water or changing their character?

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† Chief Engineer, Board of Water Supply, New York, N. Y.

Mr. Story. I don't know as to that. I always thought that the aërator acted in three ways: That it put oxygen into the water so that the filters would run better; that it broke up the organic matter more or less and probably rendered it more easily handled by the filter; and that it oxidized the iron so that the iron was removed during filtration. I might say that we have discovered anabaena in the filtered water but once, when we found one straggling strand in the sample which was taken on the day that the reservoir water was the worst. We have found a little asterionella at one time and another, but not in any appreciable number; and we have found a few colonies of cœlosphærium. With these exceptions, the filtered water has been entirely free from microscopical organisms of any kind.

Mr. Robert S. Weston.* I would like to ask Mr. Story if the introduction of this better water has had any effect upon the spring water business in Springfield?

Mr. Story. I think that it has, although I have no statistics on that point. I know that a great many people who had always used spring water in the summer gave it up after the filters were started. This fall, after we shut down, all the old dealers, some of whom had retired from the business, started in again. The Consolidated Ice Company, big dealers in ice, started up their artesian well and did a large business during the time when the reservoir water was bad.

Mr. William S. Johnson. I would like to ask if you have any evidence that the filters would not have done their work if the water had not been applied intermittently; if they had been run continuously between cleanings?

Mr. Story. That question is a little difficult to answer, inasmuch as the filters were always run intermittently and were given as much time to rest as we could give them. My impression is that they would not take care of the water as well at times without the aëration of intermittent filtration. The operation became pretty difficult this last fall, when the plant could only be shut down four hours a day so that the intermittent action practically ceased. I think that we were reaching a stage where they could not have taken care of the dirty water that existed at the time we shut down for the winter, unless more of a rest could have been given to the beds each day.

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* Sanitary Expert, Boston, Mass.

Mr. Johnson. The reason I ask that question is that two years ago I constructed filters at South Norwalk, Conn., for the treatment of a water very similar to that of Springfield. I think the water from the South Norwalk reservoir was worse, if it could be worse, than the water from Ludlow reservoir. The filters were built after the designs of Mr. H. W. Clark, and the plans provided for double filtration and aëration. The work was partly completed last spring, but as the appropriation was exhausted, only the primary filters were filled with sand.

The primary filters were started last May, and have been operated continuously at a rate of about 3 000 000 gallons per acre per day. As nearly as I can learn, they have given excellent satisfaction even with the single filtration, although the water has been about as bad as during any previous season and certainly worse than the Springfield water has been since the filter was started. There was, however, one short period of a few days when some complaint was made in regard to the odor of the water in certain parts of the city. That was just at the last of the epidemic of anabaena, and it was evident that if the epidemic had continued there would have been trouble all over the city.

Mr. Harold K. Barrows.* As to the kind of gravel or sand used in the filling of the filters, I think Mr. Story said that the effective size was made 0.3 millimeter, and that the car loads were sampled and tested and a rough analysis made on which to base the acceptance or rejection of a particular car load Was this figure the result of experiment, or just why was it used?

Mr. Story. I do not know that I can answer that question, as I was not there at the time. I think that was the figure which Mr. Hazen considered to be about the proper one for the construction of this plant. The average was probably somewhere around 0.3 millimeter. I have found analyses of car loads which are down below 0.2, and some of them would go considerably above 0.4, but there wasn't any great quantity of sand which went below 0.25 and not very much which went in above 0.35. It was pretty fairly uniform.

I might say in regard to the question of aëration, that Mr. Hazen has considered the aërator efficient enough so that one of

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the features of our new filter on the Little River supply is an aërator which is to be run before filtration at any time that there is any taste or odor in the water. There is enough head at the plant so that this can be put in, and it will be used when it is deemed necessary.

Mr. Harry W. Clark.* I think Mr. Story made a mistake in speaking about the filters the State Board of Health operated at Ludlow. I think he stated that all those filters failed, at least during some part of their period of operation. My remembrance is that, of a dozen filters operated there, only one failed during any part of its operation, and that was when the epidemic of anabaena was at its height, and we always considered that failure a rather abnormal occurrence. But even at that time the effluent when aërated had very little odor, and the secondary filter that we were operating removed the slight odor remaining.

Those early experimental filters did just what Mr. Story says the present Ludlow filters do, they remove from 30 to 85 per cent. of the color during the worst period of the summer. That is, the worse the water was in the reservoir, the more iron it contained; and the more anabaena, the better was the color reduction by the filters, owing to the precipitation of this iron over the surface of the filter and the coagulation of coloring and other organic matters by this iron.

I make the following quotation from my report upon the experiments at Springfield on pages 352 and 353 of the report of the State Board of Health for 1901:

REMOVAL OF ORGANISMS.

" From the beginning of the period of operation of the large filter, namely, December 21, 1900, — until August 21, 1901, very few organisms were found in its effluent, and these few were chiefly Diatoms and Zoöspores. Beginning, however, on this latter date, there was a period of poor operation of the filters, owing to the various causes already stated, during which anabaena passed through the filter, and upon several days in large numbers. This period lasted until September 17, after which time the effluent was free from organisms. None of the organisms that passed through this filter, however, passed through Filter G, receiving this effluent, and it is especially noticeable that Filter C, operating at a higher rate than the large filter, and receiving also reservoir water, al-

* Chemist, Massachusetts State Board of Health.

lowed no organisms to pass through it, even during the period when the reservoir water was in its worst condition, its good work in this respect being due undoubtedly to the fact that by better operation of the filter no disturbance of the sand had occurred. Filter E also eliminated all organisms reaching it in the applied water.

REMOVAL OF ODOR.

"Summarizing the discussions upon this point given upon previous pages, it has been found that practically all positive odors were removed by single filtration except during the period of high numbers of anabaena and fermentation of organic matter in the reservoir. During this period single filtration through sand filters at rates of 2 500 000 and 5 000 000 gallons per acre daily failed to remove the odors, but double filtration, even with the secondary filter operating at a rate of 10 000 000 gallons per acre daily, was entirely successful in removing all odors remaining in the water that had passed through the primary filter, although this primary filter was poorly operated at this time. This result was aided by the aëration of the water before passing to the surface of the secondary filter."

I should like to say a word or two, also, in regard to the removal of coloring matter by the precipitation of the iron present in the Ludlow water during these experiments. The fact that this color removal by the iron was recognized by us was unfortunately not mentioned in the report of the operation of those filters, and hence it has been claimed that we failed to observe this phenomenon. However, if any one will take the pains to read previous reports of the State Board of Health he will find that at the experiment station during 1900, for instance, water made highly colored by keeping in contact with decaying organic matter was afterwards placed in contact with iron "to see if enough iron would be taken into solution by the dissolved gases of the water to subsequently coagulate and precipitate as hydrate, carrying the coloring matter with it." (Page 459, Report of 1900.) Considerable work of this sort was done in that year previous to the work at Ludlow, and in the Report for 1899, in an article on the "Occurrence of Iron in Ground Waters and Experiments upon Methods of Removal," considerable discussion is given of the removal of organic matter in colored ground waters by the oxidation and precipitation of the iron present.

Mr. Story. Mr. President, I was not aware that I had made a mistake in mentioning the fact I did. I had always considered that because Mr. Blake recommended in the way he did against filtration of the Ludlow water, and the fact that the State Board of Health had seconded his recommendation, that filtration was considered a little doubtful for Ludlow. I realize that the filters did, with one exception which Mr. Clark speaks of, take pretty good care of the water during the summer, and perhaps I ought to qualify the statement I made before to that effect. Without the aëration the filters would not take care of the water.

Mr. Clark. I think the State Board of Health did consider it doubtful that filtration of the Ludlow water was the right thing to do at Springfield. I never had any doubt myself that double filtration of the Ludlow water would produce satisfactory effluent. I thought single filtration would generally. I think the speaker stated, however, that Mr. Hazen felt rather doubtful about the results of these filters when he built them, although he knew they would improve the water, as they did.

Mr. Story. Mr. Hazen stated at a meeting in 1907, in Springfield, that he did consider the Ludlow filters more or less of an experiment. I think his words were something like these: That he knew the plant would do a great deal for the water, but he didn't know how much, and that the chief difference between the Ludlow filters and the State Board of Health filters was that the people would be the ones who would judge, and the analyst at the plant would not be the man who would determine the success or failure of the filters.

Mr. Frank L. Fuller.* I would like to ask if the water after it is filtered is pumped to a distributing reservoir.

Mr. Story. No, sir; it is not pumped. The old basin, which was originally a part of the reservoir, is used as a clear water basin. The water is pumped from the reservoir through the aërator on to the beds, flows down through the underdrains into the big drain, and out through a flume into the middle of the storage and equalizing basin. I might say in that connection that I always tried to keep down the amount of water which was stored during the summer when the weather was pretty hot, so that there wasn't much more than a day's supply on hand. During

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the fall, when there wasn't so much trouble with the growth of organisms in the filtered water, I would keep considerably more on hand — between two and three days' supply.

Mr. Johnson. Did you get any growth in the basin?

Mr. Story. We did at times, but the growth would disappear as we cut down the amount of water in the basin. If I found that anything was starting to get a foothold in the basin, I cut down the hours of pumping for the succeeding two or three days, and dropped the amount of water we had on hand. I might say that the water delivered to the city is not quite as good as the water which is freshly filtered. There is some deterioration on standing in the sunlight, but not enough so that it is of any great consequence. The water in the city has always been practically tasteless and odorless. If this had been built for a permanent plant, the basin would probably have been covered over, but it could not have been done without a great deal of expense, and that expense wasn't thought worth while.

Mr. George H. Snell.* I would like to ask Mr. Story with regard to the economy and efficiency of the pump. We have a similar pump in Attleboro.

Mr. Story. The pump which we have is a centrifugal pump run by a steam turbine. The data at hand are a little indefinite. The pump, as I said, is rated at 20 000 000 gallons in twenty-four hours, and we never have been able to devise a way of measuring just what the pump would throw. We tried to use the method, which is described in one of the Proceedings of the American Society of Civil Engineers,† of measuring the head that exists on top of the 30-inch discharge pipe, and in that way to get an idea what the discharge was. But there is an elbow in the pipe right down below the aërator, which so affects the discharge that it is considerably higher on one side of the pipe than it is on the other. We guessed as well as we could at the mean and worked out results from that with the formula which was given in the paper. We were reasonably certain from the data which we got that the pump would throw considerably over 20 000 000 gallons in twenty-four hours, but how much more we were never sure. If the filters had concrete bottom and sides, we would have some

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† Trans. Am. Soc. C. E., Vol. LVII, p. 265.

way of measuring the amount of water going into the basin, because we have a weir on the end of the flume. Mr. Hazen told me once that 500 pounds of coal for 1 000 000 gallons of water pumped was considered an economical thing for a plant of that kind, and, as I remember it, we used something like 400 pounds of coal to 1 000 000 gallons of water.

THE WATERS OF THE GREAT LAKES.*

BY R. B. DOLE.†

Possibly no bodies of water are of greater interest to sanitarians and to chemical engineers than the Great Lakes which are held in common by the United States and the Dominion of Canada, for these inland seas furnish the water supply of more than four million people in a hundred cities; they furnish water for the industrial establishments of these cities; and they furnish most of the boiler water for the enormous land and water traffic that joins the cities to each other and to the rest of the world. Such immense consumption of these waters makes their chemical composition a matter of great pecuniary interest and this interest is intensified by the fact that they supply, at least to the regions south of them, the softest waters available in sufficient quantity for urban consumption. A study of their composition is also valuable from a scientific and a practical standpoint because their comparatively equable condition allows them to serve for a standard of comparison with other waters in the northern region.

In 1906, the Water Resources Branch of the United States Geological Survey commenced a study of the waters of the Great Lakes in connection with a rather extensive investigation of the economic value of surface waters in the United States. The purpose of this paper is to present a tabular statement of the mineral analyses that were made and a brief discussion of them. One-gallon samples were collected monthly for a year from each lake at a point where it was expected that the water represented the normal quality of the discharge. Unfortunately, transportation facilities and the necessity for insuring regular collection prevented the location of sampling stations at the most desirable points. Nevertheless, it is believed that the analyses are of normal lake water with possible exception of the Lake Michigan results.

The samples of Lake Superior water were taken from St. Mary's River just above the locks at Sault Ste. Marie, Mich.; the

* Published by permission of the Director, United States Geological Survey.

† Assistant Chemist, United States Geological Survey, Washington, D. C.

Lake Michigan samples were collected from a ferryboat in the Straits of Mackinac; St. Clair River was sampled in midstream at Port Huron, Mich.; water from Lake Erie was procured at the Buffalo (N. Y.) water-works intake; and the St. Lawrence River was sampled at Ogdensburg, N. Y., since no streams of size enter between that city and Lake Ontario. The waters were shipped in special containers to the water-testing laboratory at Washington, D. C., and were analyzed from one to three months after the date of collection. The analytical data are presented in Table 1.

The analyses are stated in ionic form in parts per million, and the terms are self-explanatory. It is hardly necessary to detail the methods of analysis; suspended matter was removed before the samples were evaporated; the procedures recommended by the Committee on Standard Methods of Water Analysis were followed when practicable, the other estimates being made in accordance with methods generally recognized. On account of the lapse of time between the dates of collection and analysis, the nitrate figures probably do not represent the actual condition of the lake waters, but it is believed that most of the other estimates are within five per cent. The average total error of the analyses is about one per cent.

The most noticeable feature in a cursory examination of the analytical data is the slight variation in the concentration of the waters from month to month. From consideration of the figures for dissolved solids it can be seen that the total variation is only eighteen parts per million, or 15 per cent. An annual fluctuation of 15 per cent. in the concentration of a surface water is very small inasmuch as rivers of ordinary size may vary 200 or 300 per cent., and even large rivers like the Mississippi change 50 per cent. in their mineral content during the year. The average monthly fluctuation in the discharge of the Great Lakes is considerably more than 15 per cent., ranging from 40 per cent. in St. Mary's River to 27 per cent. in St. Lawrence River at the foot of Lake Ontario. In other words, the chemical composition of the water discharged does not bear a fixed proportion to the amount of water discharged. The reasons for this comparative steadiness in concentration are probably the absence of large tributaries and the low ratio between the areas of the drainage basins and the lake

TABLE 1.

MINERAL ANALYSES OF WATERS FROM THE GREAT LAKES.

(Parts per Million.)

Date.	Turbidity.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg.).	Sodium and Potassium (Na + K).	Carbonate Radicle (Co_2).	Bicarbonate Radicle (HCO_3).	Sulphate Radicle (SO_4).	Nitrate Radicle (NO_3).	Chlorine (Cl).	Total Solids.	Mean Elevation of Water Surface (Feet).
1906.						*Lake Superior.*							Marquette.
September 22	2	11	0.09	13	3.2	3.9	0.0	59	4.1	0.25	1.0	63	602.95
October 22	1	8.7	0.03	13	3.1	3.5	0.0	56	3.8	0.25	1.2	61	602.84
November 22	2	5.9	0.04	13	2.9	2.0	0.0	54	1.8	0.45	1.4	54	602.66
December 20	Trace	7.2	0.08	13	2.9	3.6	0.0	55	1.8	0.30	1.3	58	602.45
1907.													
January 22	Trace	4.7	0.03	13	2.9	2.0	0.0	55	1.6	0.45	1.2	53	602.22
March 22	3	12	0.04	13	3.2	5.1	0.0	55	1.7	0.35	1.1	68	601.94
April 20	1	12	0.11	13	3.1	3.5	0.0	56	1.5	0.3	1.0	64	601.94
May 23	3	4.8	0.09	13	3.0	3.0	0.0	52	1.5	0.55	1.0	57	602.12
June 22	3	4.6	0.04	14	3.2	3.3	0.0	59	1.7	1.2	1.2	59	602.55
July 22	2	5.7	0.05	12	3.0	2.8	0.0	58	1.5	1.2	1.0	55	602.75
August 22	5	5.3	0.05	13	3.1	2.9	0.0	60	1.6	0.5	1.1	66	602.93
1906.						*Lake Michigan.*							Milwaukee.
September 20	1	17	0.02	27	7.7	4.9	5.9	109	6.6	0.20	2.6	126	581.06
October 20	1	9.2	0.02	26	7.4	4.4	6.6	103	6.5	0.30	2.6	115	580.87
November 20	Trace	9.5	0.05	28	8.8	3.4	2.4	117	6.4	0.35	2.9	120	580.71
December 20	1	10	0.06	25	7.1	4.7	1.6	104	6.2	trace	2.6	108	580.66
1907.													
January 20	1	6.2	0.04	26	8.1	3.2	1.6	110	6.2	0.4	2.8	110	580.60
February 19	..	12	0.03	26	8.4	5.4	3.4	113	7.6	0.35	2.8	120	580.64
March 20	..	14	0.03	25	7.9	5.0	trace	111	7.9	0.40	2.6	117	580.70
April 21	..	8.4	0.04	26	8.1	4.7	0.0	112	9.5	0.30	2.4	115	580.96
May 20	..	9.5	0.03	27	8.7	5.4	2.6	115	7.8	0.25	2.5	121	581.09
June 20	..	8.6	0.04	26	8.4	6.6	4.5	116	7.7	0.55	3.0	120	581.50
August 20	..	11	0.04	28	9.4	4.2	3.5	120	7.4	0.40	3.2	123	581.38

1906.						Lake Huron.							Harbor Beach.
September 21	1	13	0.02	24	6.4	3.5	3.4	97	4.8	0.30	2.5	108	581.12
October 21	2	8.7	0.10	24	6.3	3.7	3.6	96	6.2	0.25	2.5	105	580.87
November 21	Trace	8.0	0.05	24	6.7	3.0	0.0	100	5.6	0.40	2.6	101	580.68
December 21	Trace	12	0.05	23	6.7	3.5	0.0	103	6.6	0.30	3.1	106	580.65
1907.													
January 21	..	12	0.03	23	7.1	5.8	0.0	99	6.7	0.40	2.5	108	580.65
March 21	..	14	0.03	22	7.2	4.7	1.2	101	6.7	0.30	2.5	109	580 68
April 21	..	14	0.04	24	7.7	5.1	trace	106	6.0	0.45	2.6	110	580.90
May 21	..	14	0.05	25	7.6	5.9	2.4	102	7.3	0.40	2.8	116	581.06
June 21	..	8.5	0.04	24	7.5	4.7	5.3	96	6.4	0.45	2.8	105	581.41
1906.						Lake Erie.							Cleveland.
September 19	2	11	0.13	33	7.1	7.2	4.1	118	12	0.40	8.0	143	572.35
October 19	2	11	0.08	32	6.8	6.3	4.8	116	11	0.00	7.9	138	572.21
November 19	17	4.2	0.04	31	7.4	5.8	0.0	124	12	trace	8.2	129	572.18
December 19	24	7.6	0.04	31	7.4	6.8	3.6	118	13	trace	8.6	136	572 42
1907.													
January 19	190	2.9	0.07	30	7.4	6.4	0.0	117	13	0.25	9.2	126	572.76
March 19	13	4.5	0.10	31	7.5	5.8	2.2	112	14	0.25	9.2	132	572.24
April 19	..	8.6	0.06	30	8.2	6.9	1.4	108	13	0.35	8.4	129	572.71
May 25	..	4.7	0.05	31	7.9	6.5	4.0	104	14	0.6	8.6	132	572.85
June 19	..	4.6	0.03	31	7.9	6.7	5.3	110	13	0.45	8.8	131	573.27
July 19	..	3.9	0.03	32	7.8	7.1	5.2	110	14	0.50	9.2	134	573.31
August 28	..	2.1	0.18	31	8.0	5.9	3.4	112	13	0.35	8.6	128	573.03
1906.						St. Lawrence River.							Charlotte.
September 18	2	9.6	0.06	32	6.9	6.2	4.2	114	12	trace	7.7	135	246.03
October 18	1	8.2	0.03	32	6.5	6.7	3.7	115	12	trace	7.2	134	245.73
November 18	5	3.7	0.05	31	7.3	6.1	4.2	114	12	0.6	7.6	128	245.62
December 24	2	6.6	0.04	32	7.1	5.7	trace	123	13	0.45	7.6	133	245.74
1907.													
January 18	3	6.6	0.04	31	7.4	6.9	3.6	117	13	0.25	7.8	135	246.26
March 18	18	5.0	0.05	31	7.3	5.4	trace	120	13	0.25	7.7	128	246.45
April 23	4	7.7	0.05	30	7.7	7.3	2.5	116	12	0.15	7.3	141	246.80
May 22	1	7.1	0.06	30	7.6	6.8	4.0	113	12	0.15	7.2	143	247.04
June 18	..	3.9	0.05	32	6.9	6.1	0.0	118	12	0.80	7.9	130	247.10
July 20	..	5.2	0.03	32	7.4	5.8	4.4	112	14	0.60	8.6	133	247.14
August 18	..	9.4	0.04	32	7.3	6.1	4.8	111	12	0.40	8.3	137	246.85

surfaces. The land surface tributary to the Great Lakes forms but a narrow rim around them. In fact, the water surface above Rochester, N. Y., is one third of the total drainage area, a condition that prevents the entrance of large rivers bringing in waters of fluctuating mineralization from affecting the quality of the lakes, and which at the same time affords excellent opportunity for the mixture of waters from small affluents. Yet the fluctuation in total solids, though small, is real and deserves consideration. Comparison of total solids with the average monthly stage of the several lakes at the time of collection shows a general, though by no means regular, correspondence of the two figures. The lakes are usually lowest during the winter months and many high values of total solids are observed during that period; on the other hand, several periods of high mineralization occur during the periods of high water. The reason for this is not exactly clear, but some light is thrown on it by comparing total solids with total precipitation determined at the meteorological stations nearest the sampling points. A plot of these two sets of figures shows much greater coincidence than the comparison of water stage and total solids, and it is found that total solids is inversely proportional to the precipitation in the majority of cases. This leads to the conclusion that local rains dilute the upper strata of the lakes, and that, as a consequence, samples of water, even when taken from the narrow lake outlets, may often reveal the effects of such dilution.

Table 2 brings together for comparison figures showing the average quality of the lakes.

Though the lake waters do not change very much from month to month, they differ a great deal from each other in their concentration. Lake Superior is least strongly mineralized. Lake Michigan is twice as high in total solids and Lake Huron is only a little less mineralized than Lake Michigan. Lakes Erie and Ontario are practically alike in their mineral content, having about two and one-half times as much solids in solution as Lake Superior. The chief reason for this constant and striking difference is the dissimilarity of the geologic formations in the basins tributary to the lakes. All around Lake Superior igneous and crystalline rocks predominate, granite, schist, gneiss, and basalt occurring in great abundance. Since these silicate rocks are hard and

TABLE 2.

THE AVERAGE QUALITY OF THE GREAT LAKES.*

Source.	Parts per Million.				
	Lake Superior.	Lake Huron.	Lake Michigan.	St. Lawrence River.	Lake Erie.
Turbidity	2.	Trace	Trace	4.5	41
Silica (SiO_2)	7.4	12	10	6.6	5.9
Iron (Fe)	0.06	0.04	0.04	0.05	0.07
Calcium (Ca)	13	24	26	31	31
Magnesium (Mg)	3.1	7.0	8.2	7.2	7.6
Sodium and potassium (Na + K)	3.2	4.4	4.7	6.3	6.5
Carbonate radicle (CO_3)	0.0	1.8	2.9	2.9	3.1
Bicarbonate radicle (HCO_3)	56	100	112	116	114
Sulphate radicle (SO_4)	2.1	6.2	7.2	12	13
Nitrate radicle (No_3)	0.5	0.4	0.3	0.3	0.3
Chlorine (Cl)	1.1	2.6	2.7	7.7	8.7
Total solids	60	108	118	134	133
Salinity	58	108	117	131	132

difficultly soluble, Lake Superior receives few affluents bearing large quantities of dissolved matter. Lake Michigan and Lake Huron, on the other hand, lying on either side of the southern peninsula of Michigan, are affected by the drainage from the limestones and sandstones of the sedimentary series, and as a result their mineralization is greatly increased. Dilution by the softer water of Lake Superior is probably the reason why Lake Huron water is less mineralized than that of Lake Michigan. As stated before, it is possible that the samples of water from the Straits of Mackinac do not represent the actual quality of Lake Michigan water. Samples from the lake at Milwaukee and at Chicago show somewhat higher mineralization and a slightly different composition of the mineral residue. Since lakes Huron and Michigan have practically the same water level and the straits are wide, it is probable that the wind could establish a westward current, thus mixing the waters of the two lakes at the sampling point. Lake Erie water in its increased mineral content evidences the continued effect of calcareous sedimentary formations. Lake Ontario, being small in comparison with the rest of the system,

* The above figures are averages of ten or more analyses from each lake.

and being surrounded by formations similar to those around Lake Erie, does not have much effect on the concentration of the effluent and may be regarded as merely an expanded outlet of Lake Erie. It is probable that forestration, sedimentation, and the relation of rain-fall to run-off also influence the relative composition of the lake waters.

TABLE 3.

AVERAGE CHEMICAL COMPOSITION OF THE MINERAL MATTER IN THE GREAT LAKES.*

Source.	Per Cent. of Anhydrous Residue.				
	Lake Superior.	Lake Huron.	Lake Michigan.	St. Lawrence River.	Lake Erie.
Silica	12.8	11.1	8.5	5.3	4.5
Calcium (Ca)	22.4	22.3	22.1	23.5	23.4
Magnesium (Mg)	5.3	6.5	7.1	5.5	5.8
Sodium and potassium (Na+K)	5.5	4.1	4.1	4.8	4.9
Carbonate radicle (CO_3)	47.5	47.4	49.6	45.7	44.8
Sulphate radicle (SO_4)	3.6	5.8	6.1	9.1	9.8
Nitrate radicle (NO_3)	0.9	0.4	0.2	0.2	0.2
Chlorine (Cl)	1.9	2.4	2.3	5.9	6.6
Ferric oxide (Fe_2O_3)	0.1	0.0	0.0	0.0	0.0
Salinity	58	108	117	131	132

Not only do the lakes differ in mineralization, but the upper and lower lakes are dissimilar in the composition of the material dissolved in them, as shown by Table 3. They are all essentially calcic carbonated waters with the sulphates and chlorides subordinate. The composition of the three upper lakes is practically the same, showing only a slight reduction in per cent. of silica and a corresponding increase in magnesium and sulphates in Lake Huron. The two lower lakes are nearly alike, but the character of the drainage water in the lower part of the system materially affects the composition of the lake waters by decreasing the per cent. of silica and carbonates and doubling the per cent. of sulphates and chlorides, thereby making the waters less desirable for industrial use.

* The above figures are averages of ten or more analyses from each lake.

Before leaving the composition of the dissolved matter, it may be allowable to diverge long enough to consider the chlorine content of the lakes in connection with human contamination. The average chlorines are as follows, in parts per million: Lake Superior, 1.1; Lake Michigan, 2.7; Lake Huron, 2.6; Lake Erie, 8.7; St. Lawrence River, 7.7; the chlorine content increasing from west to east. Lake Erie at Buffalo carries six parts per million more chlorine than Lake Huron at Port Huron. The population of the drainage system increases in density from Duluth eastward and it is, therefore, interesting to consider the influence that the chlorine of civilization has upon the lake waters. In Table 4 the chlorine due to this cause has been calculated in parts per million. The figures representing population have been estimated from the best obtainable sources and two thirds of the population of Chicago has been deducted from the total for Lake Michigan basin, since the sewage of Chicago is discharged southward. The amount of chlorine contributed per person per day has been taken as 0.045 pound, the figure used by Stearns * in his estimates for the Massachusetts State Board of Health.

TABLE 4.

Chlorine due to Human Contamination.

Lakes.	Estimated Population.	Discharge Sec.-Feet.	Equivalent in Chlorine. Parts per Million.
Superior	400 000	72 000†	0.05
Huron and Michigan	2 400 000	195 000†	0.10
Erie	6 000 000	220 000†	0.23
Ontario	8 200 000	255 000‡	0.27

This table needs no comment; the last column proves how little effect population has upon the chlorine content of the Great Lakes. If all the people in the United States and in the Dominion of Canada were living in Lake Erie Basin alone, the resulting increase in chlorine would not equal the present difference between the chlorine contents of Lake Erie and Lake Huron. The increase in chlorine is undoubtedly due to solution of salt deposits and of

* Stearns, F. P.: Report Massachusetts State Board of Health, 1890, Pt. 1, p. 680.

† Regulation of Lake Erie. United States Engineer Corps, H. R. Doc. 220, 56th Cong., 1st Sess., p. 7.

‡ Survey of Northern and Northwestern Lakes. War Dept., Engineer Corps, Bull. No. 18, 1908, p. 330.

chloride-bearing rocks in the sedimentary formations lying in Lake Erie Basin.

Comparison of the lake analyses with those of tributaries to the system demonstrates that the lakes are almost invariably softer than their affluents. The reason for this difference is apparent; since the lake surfaces are large in proportion to their corresponding land drainages, a great part of the rain falls directly into the lake waters and dilutes them; on the other hand, rain falling upon the land surface becomes more or less impregnated with mineral salts before it reaches the lakes in the normal run-off. This is an important point in the industrial consumption of lake water and shows the advantage of locating intakes outside the influence of tributary streams. The extent of the difference in mineralization may be seen by consideration of Table 5, which gives the average total solids of a few tributaries of this system. The list might be greatly extended if necessary or desirable.

TABLE 5.

Average Total Solids, Tributaries of the Great Lakes.

River.	Location.	Average Totals Solids. Parts per Million.
Grand	Grand Rapids	258
Kalamazoo	Kalamazoo	242
Maumee	Toledo	298
St. Louis	Cloquet	137

Grand River at Grand Rapids and Kalamazoo River at Kalamazoo carry over twice as much mineral matter in solution as Lake Michigan, into which the rivers flow. St. Lawrence River, which enters Lake Superior at Duluth, is nearly three times higher than the lake in total solids. St. Clair River, with an average discharge two hundred times greater than that of Maumee River, brings only fifty times more dissolved matter into Lake Erie. These computations have taken no account of suspended matter, which is very high in many of the streams entering the Great Lakes. The suspended matter brought into the lakes is practically all deposited by sedimentation, so that the waters are not turbid except when they are locally agitated by storms or by other agencies.

In conclusion, it may be said that the lake waters are low in mineral content and that they are normally free from turbidity. The nature of the dissolved constituents is such that the waters can be used for boilers and for most other industrial purposes without purification. The small amount of iron, sulphates, and chlorides especially recommends the waters for industrial and domestic use whenever they can be economically obtained.

THE DEVELOPMENT OF THE CAMAGUEY WATER WORKS, CUBA.

BY HENRY A. YOUNG, C.E.

[*Read September 9, 1909.*]

To those members of the Association practicing water-works engineering in the North, the description of the design and construction of a complete water works in the tropics may prove of interest.

In a physical way, Cuba offers a rather difficult proposition for municipal water works. The island is approximately seven hundred and fifty miles long and varies in width from fifteen to eighty miles. As the rivers flow either to the north coast or the south coast, it can readily be understood that they are short. The majority of them are likewise subject to contamination. Still further, the dry season is protracted, and during this season the flow in the streams drops in many cases to the vanishing point, while in the rainy season there are floods after heavy rains that are apt to prove disastrous. In general, the term " river " as used here is an evolution of Spanish courtesy, for most of the interior " rivers " would hardly fulfill the term " creek " as used in the North.

From the financial or political side, works of this nature are facilitated by the fact that all public work is done by the general government. Local taxes supply the provincial and town governments with barely enough money to cover running expenses, and it is only a few of the larger cities that have issued bonds for municipal work. The customs duties are collected by the general government, and much of the money received in this manner is used in public improvements all over the island. As a result, when a town or province finally gets a bill through Congress, the chances are that the appropriation will be entirely sufficient to do the work properly, and, of course, the locality does not suffer a direct drain on its resources.

In January, 1904, Congress appropriated \$200 000 for preliminary studies and the getting up of a project for the Camaguey water works. Two years and a half later, it appropriated \$600 000 more, making a total of \$800 000. Two years were spent over the preliminary work, but the project developed was inadequate. After the second appropriation had been made, a larger and better project was worked out, with the result to be described.

Camaguey is a very old town, in fact, one of the oldest in the western hemisphere. The streets are narrow, from eight to ten meters wide, and very crooked. Sidewalks vary in width from a half meter to a meter and a half and are at irregular heights and grades. The population of the city is about thirty thousand. Up to the present, drinking water has been obtained partially from wells, but mostly by catching rain water and storing it in cisterns and large earthern vases called "*tinajones*," set up in the patios.

No expense was spared in locating the supply for the new system. The country was examined for a radius of twenty-five miles around the city. There were several small creeks in the immediate vicinity, but as none of them had the capacity necessary, and as they all passed through a flat grazing country, more or less settled, they were contaminated and had to be discarded. It was then proposed to obtain the water by means of driven wells. This scheme, also, had to be abandoned, after an examination of the four driven wells in the city, for the following reasons: In the first place, there was no artesian effect on the ground water, and it was not known what the result would be if it was drawn upon by twenty to thirty wells. Secondly, the water is very hard, and in some of the wells has an obnoxious taste when warm.

Ultimately it was decided to draw upon the "Rio Pontezuela Grande," a good sized creek about 14 miles (23 kilometers) north of the town. This creek had a drainage area of about 80 square kilometers in a totally barren area of *sabana*, lying between two ridges of hills. It is not polluted because there is absolutely no one living within the district. The hills are composed mostly of a poor class of iron ore, and the *sabana* is fit for little but grazing, so the danger of future pollution is slight. Records of the discharge of this river show that even in the best years the flow will be at times

less than the supply required, and during the exceptionally dry seasons of 1906–1907 and 1907–1908 the discharge dropped to about one quarter of the normal supply required by the present population. However, this is the condition that would usually be found in Cuba, and as there was a fine site for a dam on a rock bottom, it is proposed to form a reservoir impounding a four months' supply that will carry the city through any possible dry season. Fig. 1, Plate I, is a picture of the Rio Pontezuela Grande, taken within the reservoir site.

In designing the system, a consumption of 60 gallons per capita per twenty-four hours was allowed. Considering the fact that for centuries the people of this town have lived on the limited supply of rain water that they could catch, this allowance ought to be sufficient. Further it has been the expectation to require meters on the house services from the start and thus prevent unnecessary waste. To provide for the future growth of the city an allowance of 54 per cent. increase in the population was assumed to occur within the next twenty years. This gave a population of 46 200, which will probably not be reached in that time, as this is a cattle district, with little chance for the development of manufacturing.

The complete system consists of a reinforced concrete dam at the headworks, with a large impounding reservoir; a reinforced concrete pump house containing a vertical triple expansion pumping unit; about 6 kilometers of 18-inch cast-iron force main; a double tank; reinforced concrete covered reservoir; about 17 kilometers of 20-inch cast-iron supply main, and the city distributing system. At the time of writing, all of this work is practically completed with the exception of the pumping plant and the dam.

The concrete-steel dam will be 278 meters long and 10½ meters high. This type was determined upon as being best suited to the locality, largely because the headworks are 23 kilometers away from the city over exceptionally bad roads or trails, which are almost impassable in the rainy season. Consequently, the hauling of materials is an important item in the total cost. Also, there was good concrete rock right on the site of the dam, so that practically the only materials that will have to be hauled will be the cement and steel. Unfortunately, a new appropriation will have

Fig. 1. The Rio Pontezuela Grande; within the Reservoir Site.

Fig. 2. Method of Erecting the Telegraph Poles.

to be obtained for this dam, and so its construction will probably be delayed a year or two. It is, however, an essential feature of the complete system and will be built before the entire town is served with connections.

In determining the size of the 20-inch supply main it was assumed that the rate of flow during the hours of maximum consumption would be 50 per cent. in excess of the normal. For the normal delivery at the future population of 46 200 the main would have to carry 2 772 000 gallons per twenty-four hours, and allowing for the 50 per cent. increase during the hours of maximum consumption, or at the rate of 90 gallons per capita per day, the total maximum discharge of the main would be 4 158 000 gallons per twenty-four hours. The loss of pressure for this discharge was figured by Bernoulli's theorem, $h = 4f \frac{l}{d} \frac{v^2}{2g}$, and found to be 88.96 feet. This loss was increased by 60 per cent. to cover future deterioration in the pipe line in the next twenty years, or an allowance of 15 per cent. for each period of five years, as recommended by Coffin, Weston, and others. The static head between the tanks and the entrance to the city is 244.43 feet. The total head lost by friction, including 60 per cent. for deterioration, will be 142.29 feet. This will leave a pressure at the entrance to the city, during the hours of maximum consumption twenty years hence, of 102.14 feet, or 44.33 pounds per square inch. The velocity in the supply main under the discharge of 4 158 000 gallons per twenty-four hours will be 2.95 feet per second. For the present population of 30 000 during the hours of maximum consumption, or at the rate of discharge of 2 700 000 gallons per twenty-four hours, the effective pressure at the entrance to the city will be 205.1 feet, or 88.9 pounds per square inch. It will be seen that the city will start out with a very good pressure, and it is hoped that the assumed conditions for the future have been taken so high as to never be actually reached.

In determining the size of the 18-inch force main the same principles were used as in the supply main. The amount of water required by the present population of 30 000 people, or 1 800 000 gallons per twenty-four hours, was taken as a basis, to be pumped in fourteen hours. For future increase it was considered that the

pumps could work double shifts up to a total of twenty-two hours, if ever required. The static head, including suction, was found to be 296.6 feet, and the friction head, plus 60 per cent. to cover deterioration, 58 feet. There was a small velocity head of 0.11 feet, making a total head against which the pumps had to work (as a maximum) of 354.7 feet. The velocity of flow in the main under these conditions was 2.7 feet per second.

Throughout the force main and supply main air vents, consisting of 1-inch globe valves located in concrete boxes, are placed on every summit; and 6-inch blow-offs are located in manholes at the sumps. Stop valves are located about every third kilometer, so that the various sections of the line can be isolated in case of trouble. A strip of land 10 meters wide has been purchased throughout the entire length of the line.

As before mentioned, the pumping plant has not yet been constructed and there has been more difficulty in this one branch of the work than in all the rest put together. It was first proposed to install two units, with provision for a third, consisting of four-stage centrifugal pumps, gas engines, and suction gas producers. The pumps would have had a water horse-power each of 96.3. Assuming an efficiency of 70 per cent. for the pumps and 5 per cent. loss in the belt, the brake horse-power of the engines would have been 145. The capacity of the pumps was taken as 1 075 gallons per minute against the head of 355 feet. Plans were gotten up on this basis, which included a concrete steel pumping plant, but after hanging fire for about a year they were rejected by the Secretary of Public Works, who stated that his action was taken after a study of the Palatino pumping plant at Havana which was of similar design and had been in operation about a year. This plant, it was claimed, had never given entire satisfaction. The secretary then had plans prepared in his own office for a plant consisting of one triple expansion high-duty pumping engine and auxiliaries, two water tube boilers, and one fuel economizer. The building was also of concrete steel with provision for the installation of a second unit later. Bids were opened on December 28, 1908, for this steam plant, but a contract has not yet been let; and it is understood that the new secretary, who has just come in with the recently formed Cuban government, will reject all bids, con-

sidering them excessive. The future only can decide what will be the final style of plant adopted. However this much-mooted question may be settled, it is certain that the building for the pumping plant will be of concrete-steel, for the same reasons as given for the proposed dam. It is quite likely that a temporary pumping plant will be installed so as to furnish the city with water shortly, until the final plant can be built. As there will be probably only a few hundred connections made during the first year of operation, a pump from one of the other projects on the island could be used and worked day and night at no great inconvenience or expense, and the system thus put into operation.

The double tank concrete-steel reservoir is located on the top of a hill called the "Punta de Garcia." Each tank is 30 meters square by 4 meters deep under the beams. The two tanks together have a capacity of 1 800 000 gallons, which is the normal amount of water required per twenty-four hours by the present population of 30 000 people. The tanks are arranged with an inlet chamber or gate house at the end of the 18-inch force main and an outlet gate house leading to the 20-inch supply main and the city. The structure is set half in the ground and half out, but a bank is raised around the outside to within a meter of the top. Both tanks can be used together or either one separately, thus permitting of cleaning. There is also a direct connection through the tanks from the force main to the supply main so that water can be pumped direct to the city if required. The entire structure is of reinforced concrete, the roof being 3 inches thick and reinforced with Clinton wire mesh. Across the center of each roof extends what was termed in Spanish a "*saltillo*" and in English might be likened to the "monitor" on a factory building. This is open to permit of ventilation; but the openings are screened to prevent the entrance of mosquitoes and dust.

Fig. 1 shows the arrangement of the tanks and the piping. Fig. 2, a longitudinal section through both tanks; Fig. 3, a cross-section through the gate houses; Fig. 4, a partial section through the roof; and Fig. 5, column details.

In designing the various concrete members for the reservoirs the conservative straight line formula for reinforced concrete beams was used. The ultimate crushing strength on concrete

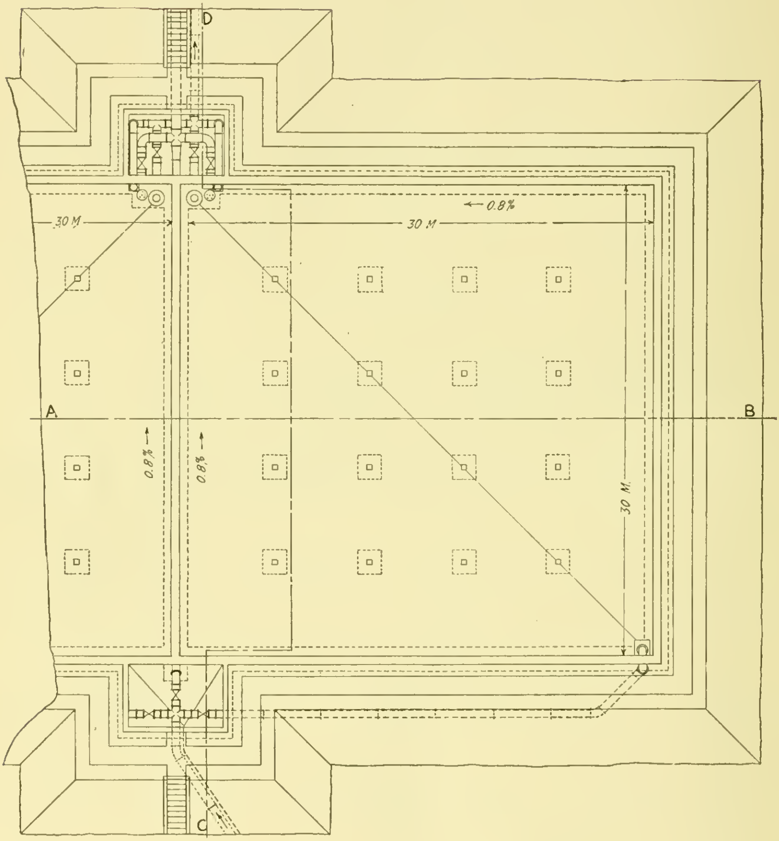


FIG. 1.

A PARTIAL PLAN OF THE RESERVOIR, SHOWING THE PIPING.

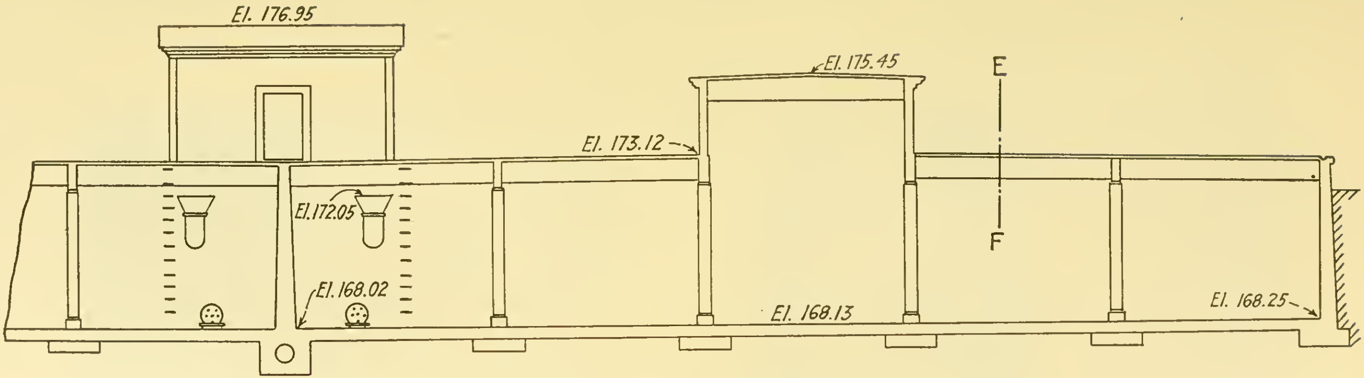


FIG. 2. CROSS-SECTION ON LINE AB (FIG. 1).

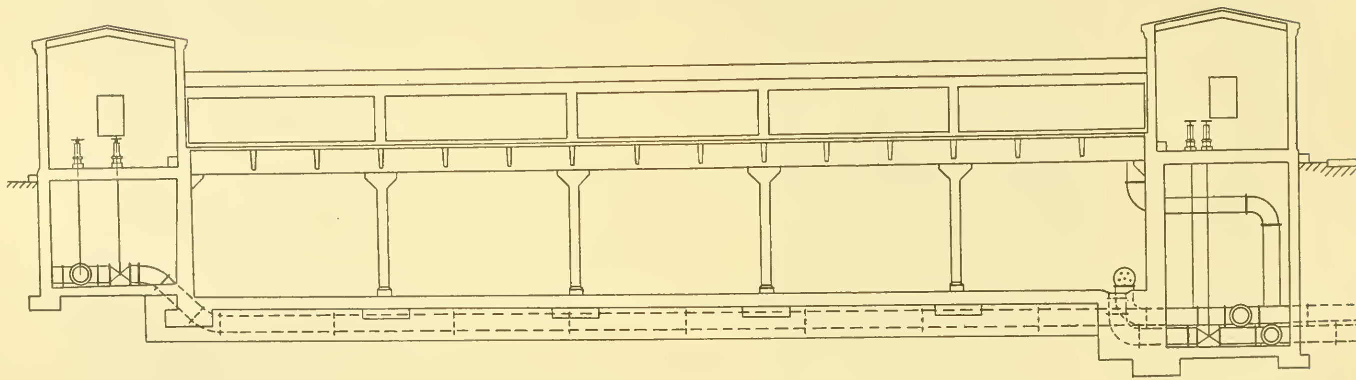


FIG. 3. CROSS-SECTION ON LINE CD (FIG. 1).

These cross-sections show the drains, outlets with strainers and overflows, as well as the general arrangements of piping, columns, etc.

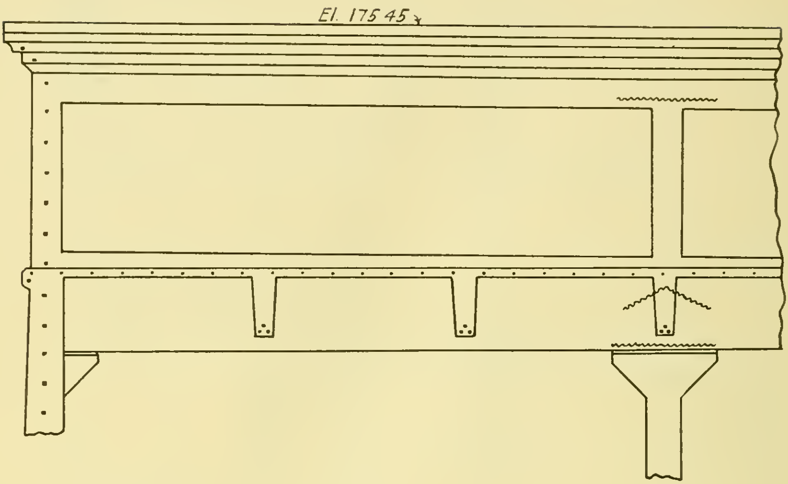


FIG. 4.

A PARTIAL SECTION ON EF (FIG. 2), SHOWING THE ROOF BEAMS, COLUMNS AND ELEVATION OF "SALTILLO."

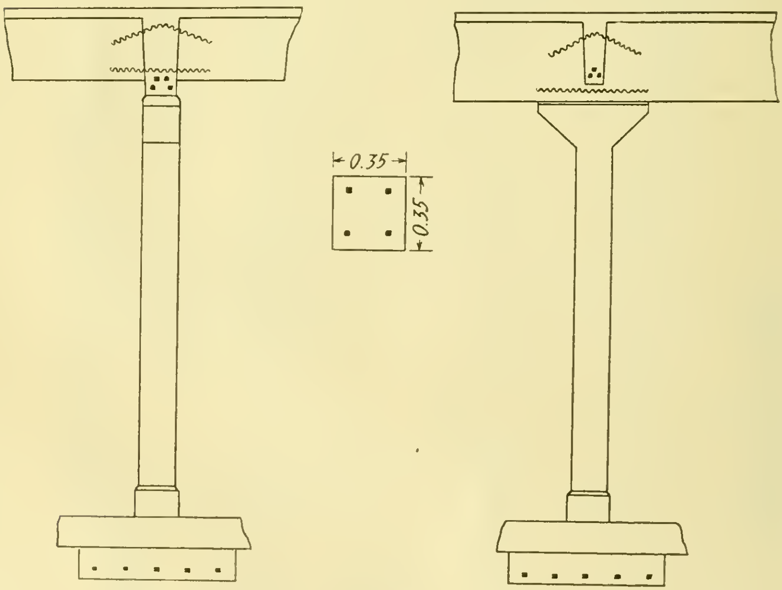


FIG. 5.

COLUMN DETAILS.

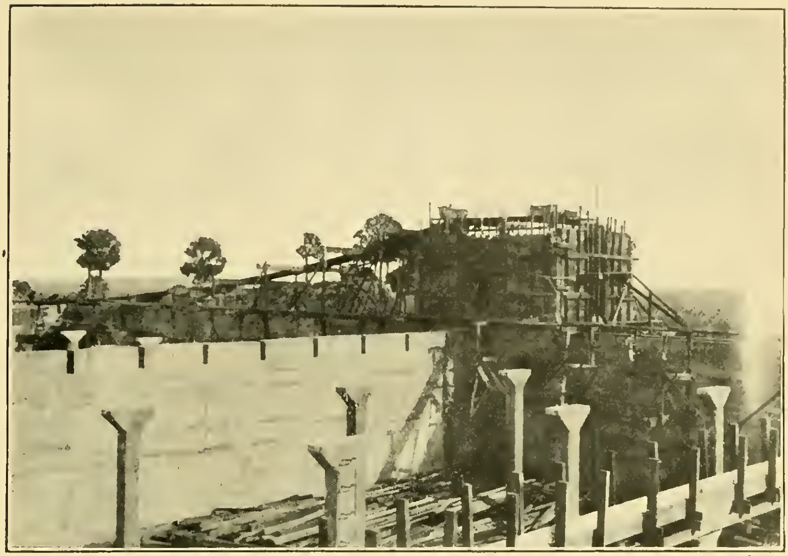


FIG. 1. THIS PICTURE SHOWS THE HOLES LEFT IN THE WALLS FOR THE ROOF BEAMS.

FIG. 2. THIS PICTURE SHOWS THE METHOD OF TAMPING THE EARTH FILLING AROUND THE WALLS.

was taken at 2 000 pounds per square inch, and the elastic limit of steel at 30 000 pounds per square inch, a factor of safety of 3 being allowed on these figures. The exterior walls were considered as a cantilever beam to support the earth pressure of the backing. They were not reinforced to sustain the water pressure, as it was specified very rigidly that the backfill was to be rolled in 6-inch layers with a 5-ton roller, water tamped, or compacted in some equivalent manner to the satisfaction of the engineer. Dependence is placed upon this backing to sustain the water pressure. So as not to throw outside strains on the walls, they were built leaving openings for the roof beams and a rabbet for the roof. These openings will be painted with oil to insure separation of old and new concrete, and a compression joint of two or three layers of tar paper will be placed in the rabbet, between the walls and the roof. In this manner the beams and roof can expand and contract without straining the walls or interfering with their freedom to act as cantilevers. Fig. 1, Plate II, shows the openings in the walls left for the beams. It also shows the columns and the commencement of the forms for the beams with their supports. Fig. 2, Plate II, shows the method of hand tamping the backfill against the wall in cramped places where it was difficult to use any other method. These four men went over and over each layer until it was well compacted.

There is one feature of the reservoir plans which should not be passed without mention. Too often large concrete work is let to a contractor without a complete bending list for the reinforcing steel, which means trouble and unpleasantness throughout the entire work. In this case it was determined that the information should be furnished in full. This was accomplished by a bending list in tabular form. The first column of this table showed the general location in the structure of each bar; the second, its position, whether vertical or horizontal; the third, the number of bars of each class; the fourth, the size of the bars; and the fifth, the total length of the bars before bending. The next ten columns relate to the bending and give, first, the distance to the first bend, then the angle of the bend, next the distance to the second bend, the angle of the second bend, etc. The sixteenth column refers to the proper sketch showing the

proper form for each class of bar, and the last column gives the sketches showing all the various methods of bending. This list paid for itself a thousand fold. The bars were bent by the ordinary lever bender supplied with lugs for gripping the bar.

Plate III explains the methods of laying the 12-inch floors and gives a good idea of the number of bars entering into the reinforcement of the walls and the way that they were supported. The mixer was on the bank at one side and a chute carried the concrete to the lower level. The forms for the walls were carried up solid from the floor to the top. Concrete was mixed wet and well spaded, particular care being taken with the spading against the face of the forms, which latter were of 2-inch lumber dressed and beveled on the edges. The concrete for the walls was laid in 6-inch to 8-inch layers, each layer being carried continuously around the entire structure.

In laying out the distributing system for the city, it was found impossible to place a pipe on every street, as the expense would have been too great at this time. It was, therefore, determined to pipe the business part of the town and run a skeleton system in the outskirts in such a way that this could be filled in during the future. The system consists of four mains running across the city on San Fernando, Cisneros, Hospital, and Bembeta streets, connected by equalizers, with the remaining streets filled in with 6-inch pipe, and a few unimportant blocks containing 4-inch. The two first-named mains are built. The two last will be left for the future.

In determining the sizes of the various mains in the city, the principles advocated by Turneaure and Russel, in their work, "Public Water Supplies," pages 698 and 699, together with their dia-&ram on page 233, were used. As previously stated, it was decided that 35 pounds to 40 pounds per square inch under the maximum future conditions must be the minimum pressure in the highest parts in the city, which means that about double that pressure will be available under the maximum conditions at present.

Many points were taken at various parts of the city and the pressures worked out, assuming a fire at the point requiring the use of six 200-gallon hydrants, and also that the districts beyond would be operating under the maximum future daily draft, or at

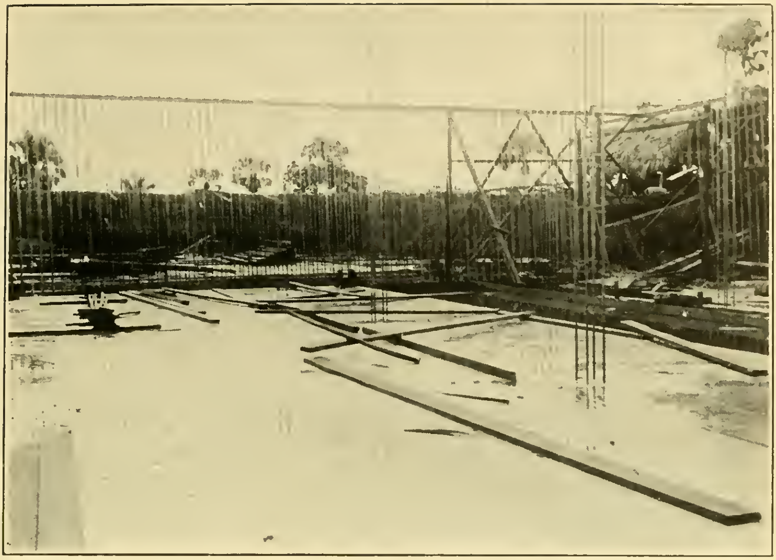


Fig. 1.

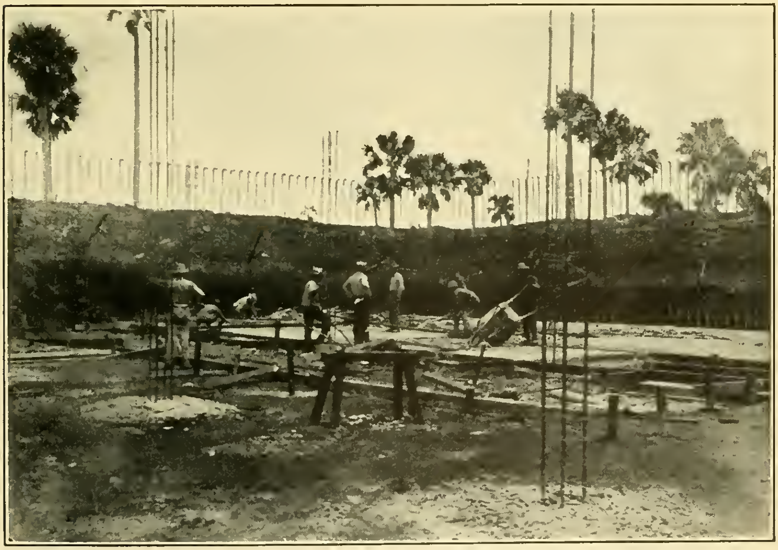


Fig. 2.

These Pictures show the Method of Placing the Concrete in the Floor, as well as the Steel Reinforcements for the Side and Cross Walls and for the Columns.

90 gallons per capita per day, with the further draft that would come upon the mains in passing through other districts in reaching the point under consideration. This latter was a difficult question to determine, as the water is drawn off successively at each succeeding block from the beginning at the 20-inch supply main. The writer has never seen a method advanced for the determination of this loss. After careful consideration, it was finally determined that a sufficiently close approximation would be obtained by first determining the total amount of water distributed by the mains in reaching the point in question and then assuming that the loss of pressure would be equivalent to that caused by the passage of one third of this amount plus that required by the districts beyond the point, plus that required for fire, was the total amount passing the length of the mains upon which the loss in pressure was computed. This it will be noted is a sufficiently severe condition, and in all probability the city will not, in this generation, increase in size to such an extent as to bring the pressures down to our worst assumption. The method referred to in Turneaure and Russel explains how a long main of various sizes of pipe can be reduced to an equivalent main of one size over its entire length. When this is accomplished the two or three mains leading to the locality can be reduced to one equivalent main, after which it is a simple matter to determine the loss of pressure for the assumed quantity of water delivered. In making the figures the carrying capacity of the 6-inch and 4-inch laterals was neglected. This increased the factor of safety and will also help to cover the deterioration in the pipes for years to come.

Sixty-eight hydrants have been spaced throughout the city. The city is divided into fifteen valve districts, to be increased as new pipes are laid hereafter. All hydrants have been provided with steamer nozzle to provide for the use of fire engines in the future should the pressures drop to the extent shown by our maximum assumptions. In order to increase the facility in locating the pipe lines in the future, they have been laid in the north and east sides of the streets in all but two or three cases. They have also been laid at certain stated distances from the house lines, as 2 meters for streets 6 meters wide or narrower; 2.5 meters for streets from 6 to 8 meters; and 3 meters for streets from 8 to 10

meters wide. Beyond this width the inspector is permitted to use his own judgment. Large scale maps have been prepared upon which are located all pipe lines, valves, specials, house taps, etc. Ties to the houses are shown, and the elevation of the top of the pipe at frequent intervals, as well as the class of material through which the trench is dug. It is hoped that this map will be of great help in the future when the sewerage system is built. All valves at the street corners are located at a prolongation to the house lines.

It might be of interest to note that the first piece of work done was to build a telephone line from the city to the headworks. A booth with a telephone apparatus was located at about every 6 kilometers. The line has proved indispensable during construction and will serve in the future to give communication between the office in the city, the concrete reservoir, and the pump house. The poles were all of hardwood, *jiqui*, set 5 feet in the ground. The line is a two-wire metallic circuit. Fig 2, Plate I, shows the method of erecting the poles.

In regard to the specifications and methods of construction, there are some items worthy of note. All pipe work has been tested section by section to a pressure of 150 pounds per square inch before acceptance. In the country these sections have been under a kilometer in length, and in the city they have usually been two blocks long. It was fully recognized that this requirement would add slightly to the expense, but as this is a pumping system, all leakage will directly add to the cost of operation. The results have proved the requirement to be of distinct value. The work has been done much better than it would otherwise have been done for the calkers knew that poor joints would show up in the test. Further, as each calker was obliged to mark his joints it was easy to locate the blame. Hardly a test has been made in the city that several bad leaks were not discovered, and usually in the country there have been from six to a dozen in each section, besides any number of smaller leaks easily fixed by a few taps of the hammer.

In addition to leaky joints, and of much more importance, has been the showing up of weak places and cracks in the pipes, that, being covered by the paint, had not been detected during laying. Over and over again such cracked pipes found during the tests

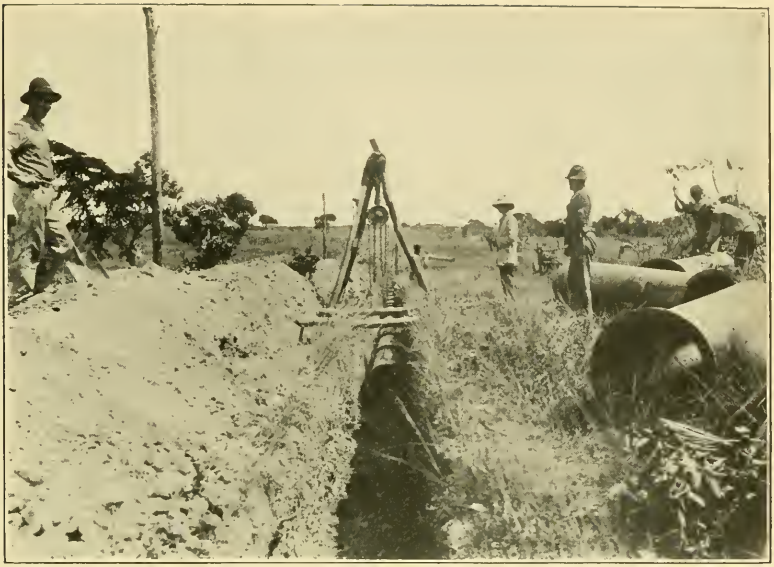


FIG. I. METHOD USED IN LAYING THE PIPES IN THE COUNTRY.

FIG. 2. PIPE LAYING IN THE CITY.

were removed and the tests repeated. Most pipes were cracked on the steamer and very often the cracks did not appear till the pressure reached 75 to 100 pounds, when they would open up and the water rush out. Actual records kept of the cost of testing show the cost to vary for the large pipe from 7 to 13 cents per meter, or at an average of 10 cents a meter. For the city distributing system the average for all sizes came to 9 cents per meter.

Another requirement of the specifications was that all scratched or bruised pipes should be painted, wherever the paint had been removed, before the pipe was lowered in the ditch. Asphaltum paint was specified. This caused very little trouble and it is well known that pipe begins to rust where the paint has been knocked off. It is hoped, in this manner, that we have added materially to the longevity of the pipe system.

The pipe specifications were based on the New England Water Works Association's Specifications, the chief variation being in the class letters used to designate the thickness of pipe, which were taken to agree with the United States Cast-Iron Pipe and Foundry Company's weights. In order to assist the contractor, a partial payment of 4 cents per kilogram was made when the pipe was delivered along the line, the balance being paid at the bid price per linear meter when the pipe was laid.

Fig. 1, Plate IV, shows the laying of the large country mains. The 18-inch pipe was mostly rolled into the ditch and allowed to fall on blocks of wood. It was then raised and shoved home by means of a lever and sling working over a sawhorse. With the heavier weights of 20-inch pipe, shear legs with a differential pulley had to be used. All large pipe was laid at such depth as to obtain 60 centimeters covering of earth over the pipe. This made the ditch for the country pipe 1.15 meters deep. The city pipe was laid at a depth of 1 meter. Fig. 2, Plate IV, gives an idea of the pipe laying in the city. For Camaguey the street on which this picture was taken is a particularly broad one.

During the construction of these water works cost data has been kept very carefully, and there are on file in the department complete costs on all classes of work. A description of our work would not be complete without recording the data obtained on at least one section of it, as a means of showing the cost of water-works

construction in Cuba for comparison with similar work in the States. For this purpose I have selected a typical section of 20-inch Class C pipe nearly two kilometers long, and submit it herewith in the shape that it was reported to the main office.

Camaguey Water Works. Cost Data.

Trenching for and Laying 20-inch Class C Cast-Iron Pipe.

(Station 1040 to Station 1138 + 1.7.)

(Deducting length of a Venturi meter.)

The work here considered is a part of the 20-inch supply line leading from the reservoir to the city of Camaguey, Cuba, and was done during the months of August, September, and October, 1908. For a distance of almost two kilometers the supply line is located in the streets of the city and in the Havana road, and it is this section that is covered by the following discussion.

The superintendent in charge of the entire contract, and the assistant superintendent directly in charge of the laying of the supply pipe, were Americans. The foremen and laborers were Spaniards and Cubans. About one third of the work was done by piece work, the prices being as follows:

Excavation	45c. per lineal meter.
Digging bell holes	26c. per bell hole.
Placing pipe in ditch	35c. per pipe.
Placing jute and pouring lead	13c. per joint.
Calking	17c. per joint.
Backfill	13c. per lineal meter.

This cost data, however, shows actual number of days worked at the current daily rates, irrespective of whether the work was done by sub-contract or by day labor.

The pipe was of Class C, designed for a working pressure of 130 pounds per square inch, having a thickness of shell of 0.91 inches, and weighing 203.7 pounds per linear foot, or 303.11 kilograms per linear meter (R. D. Wood & Co.'s specifications). The great amount of rough handling that the pipe received while in transit from the foundry in the United States to its final destination resulted in a considerable loss by breakage. The total loss due to breakage and cutting amounted to about 3½ per cent. on this section, which was the worst recorded. From 1½ per cent. to 2 per cent. would be a fair average of loss by breakage for this size pipe.

The pipe and materials were hauled from the railroad, an average distance of approximately 1½ kilometers, by ox carts, for $3.50 per

ton, which was the average price for which the hauling was sublet for the whole 23 kilometers of supply and force main.

The ditching gang consisted of 30 to 40 men. The material encountered was mostly hardpan (*cascajo*), though in two or three places a small amount of soft rock was found, and between Station 1075 and Station 1095 some easy-working earth was excavated. Taken as a whole, the excavation was a piece of difficult pick and shovel work. The trench was 1.15 meters deep and 85 centimeters wide, the depth and width being increased at the bells to allow room for calking.

A gang of 10 or 11 men was employed to dig bell holes, these men being under the orders of the foreman of the pipe-laying gang. The cost of digging bell holes was very excessive, as may be seen from the cost data. This large cost was due to the fact that a large number of the bell holes were dug twice, on account of errors in marking out the location of the bells.

The pipe was rolled to the trench and was lowered by means of a 3-ton differential pulley suspended from a tripod. The lead was poured from a large iron pail to insure filling the joint with one pouring. The pipe-laying gang consisted of a foreman and 4 laborers, and placed 25 to 30 pipe per nine-hour day.

The pipe was tested by hydraulic pressure of 150 pounds per square inch. For filling the pipe with water, a steam pump and two hand pumps, located at two cross streams, were employed. Pressure was applied by these same three pumps. The portion of pipe here considered was laid in three sections, hence three separate tests were made. In the first test a cracked pipe was discovered and had to be replaced by another pipe, and as it was located in the lowest part of the line, practically all the water was lost. The refilling of the pipe made the cost of this test almost double what it would otherwise have been. Two cracked pipes were also discovered in testing the third section, but the leakage was not great enough to prevent the obtaining of the required pressure, and these two pipes were replaced after the completion of the tests. The cost of testing is somewhat excessive.

In a few places where the ditch was filled with water, the back-filling was done by puddling, but for most of the work tamping of dry earth was the method employed, there being one tamper to each two shovelers. The entire ditch was tamped to the level of the street surface.

From Station 1092 to 1138, a distance of 920 meters, the pipe line is located along the side of a macadam pavement, and throughout this distance the excess dirt left from the backfilling was removed. Over the rest of the line, the excess dirt was simply heaped up over the ditch.

The following pages give detailed costs of the work. These costs cover all material and labor used on the work and the necessary field supervision, but do not include such general charges as the plant charge, office expenses, or bond and insurance.

All prices are in United States currency.

INSTALLATION OF 20-INCH CLASS C PIPE, 1 955 LINEAL METERS (6 414 FT.).

GENERAL CHARGE.

Labor.

	Rate.	Total.	Cost per Meter.	Cost per Foot.
Superintendent	10 days at $175.00	$58.33		
Ass't superintendent	33 ,, ,, 175.00	192.50		
Timekeeper	23 ,, ,, 1.30	29.90		
Blacksmith	10 ,, ,, 2.00	20.00		
,, helper	10 ,, ,, 1.04	10.40		
Water boy	45 ,, ,, .60	27.00		
Total labor for general charge 1 955 m. = 6 414 ft.		$338.13	$0.173	$0.053

TRENCHING (DITCH 1.15 M. x 0.85 M.).

Labor.

	Rate.	Total.	Cost per Meter.	Cost per Foot.
Foreman	33 days at $1.70	$56.10		
,,	6 ,, ,, 1.50	9.00		
Laborers	17 ,, ,, 1.30	22.10		
,,	790 ,, ,, 1.15	908.50		
Total labor for trenching 1 955 m. = 6 414 ft.		$995.70	$0.509	$0.155

(Total excavation = 1 911 cu. m. Cost per cu. m. = $0.521.)
(,, ,, = 2 500 cu. yd. ,, ,, cu. yd. = .398.)

DIGGING BELL HOLES.

Labor.

	Rate.	Total.	Cost per Meter.	Cost per Foot.
Laborers	270 days at $1.15	$310.50		
Total for digging bell holes, 1 955 m. = 6 414 ft.		$310.50	$0.159	$0.048

(540 bell holes. Cost per bell hole = $0.575.)

Total cost of trenching and digging bell holes, 1 955 m. = 6 414 ft.		$1 306.20	$0.668	$0.203

LAYING PIPES (INCLUDING CUTTING CRACKED ENDS)

Labor.

	Rate.	Total.	Cost per Meter.	Cost per Foot.
Foreman	33 days at $1.50	$49.50		
Calker	8 ,, ,, 1.75	14.00		
Laborers	128 ,, ,, 1.30	166.40		
,,	52 ,, ,, 1.15	59.80		
Total labor for laying pipe, 1 955 m. = 6 414 ft.		$289.70	$0.148	$0.045

Materials.

			Cost per Meter.	Foot.
Cost of pipe, F. O. B. Camaguey, ton (2 000 lb.)	$35.31			
Cost of unloading from cars, ton (2 000 lb.)	.19			
Cost of hauling along line, ton (2 000 lb.)	3.50			
684.3 tons 20-in. Class C pipe @	$39.00	$26 687.70		
10 gal. tar paint @	.35	3.50		
Total material laying pipe, 1 955 m. = 6 414 ft.		$26 691.20	$13.653	$4 161
Total cost of laying pipe (labor and materials), 1 955 m. = 6 414 ft.		$26 980.90	$13.801	$4.206

CALKING JOINTS.

Labor.

Calkers	41 days at $1.75	$71.75		
,,	3 ,, ,, 1.50	4.50		
,,	54 ,, ,, 1.30	70.20		
Laborers	24 ,, ,, 1.15	27.60		
Total labor calking, 1 955 m. = 6 414 ft.		$174.05	$0.089	$0.027

(540 joints. Cost of labor per joint = $0.322.)

Materials.

Lead	17 800 lb. at $0.048	$854.40		
Jute	630 lb. at .10	63.00		
Cordwood	17 cords at 3.50	59.50		
Total materials calking 1 955 m. = 6 414 ft.		$976.90	$0.50	$0.152

(540 joints. Cost of materials per joint = $1.809.)

(Lead used per joint = 33.0 lb.)
(Jute ,, ,, ,, = 1.17 ,,)

Total cost of calking pipe (labor and materials), 1 955 m. = 6 414 ft.	$1 150.95	$0.589	$0.179

(540 joints. Cost per joint = $2.131.)

TESTING PIPE.

Labor.

Foreman	4 days at $1.75	$7.00		
Calker	11 ,, ,, 1.75	19.25		
Pump engineer	44 ,, ,, 1.30	57.20		
Laborers	16 ,, ,, 1.30	20.80		
,,	80 ,, ,, 1.15	92.00		
Total labor testing pipe, 1 955 m. = 6 414 ft.,		$196.25	$0.100	$0.031

Materials.

			Cost per Meter.	Foot.
Testing plugs and miscellaneous supplies......		$21.00		
Cordwood............	11 cords at $3.50	38.50		
Total materials testing pipe, 1 955 m. = 6 414 ft..............................		$59.50	$0.031	$0.009
Total cost of testing pipe (labor and materials), 1 955 m. = 6 414 ft............		$255.75	$0.131	$0.040

BACKFILLING TRENCH.

Labor.

Foreman.............	6 days at $1.75.....	$10.50		
,, ...	6 ,, ,, 1.50.....	9.00		
Laborers..	6 ,, ,, 1.30.....	7.80		
,, ...	191 ,, ,, 1.15.....	219.65		
Total cost of backfilling, 1 955 m. = 6 414 ft. ..		$246.95	$0.126	$0.039

REMOVING EXCESS DIRT.

(Note: Excess dirt was removed from street between Stations 1092 and 1138, a distance of 920 m.)

Labor.

Foreman.............	5 days at $1.75.....	$8.75		
Laborers.............	24 ,, ,, 1.15.....	27.60		
Mule and cart.........	18 ,, ,, .70.....	12.60		
Total average cost of removing excess dirt, 1 955 m. = 6 414 ft....................		$48.95	$0.025	$0.008

REPLACING TWO BROKEN PIPES.

Labor.

Calker...............	5 days at $2.20.....	$11.00		
Laborers.............	22 ,, ,, 1.04.....	22.88		
Cart and mule.........	4 ,, ,, .70.....	2.80		
Total cost of replacing pipes, 1 955 m. = 6 414 ft..............................		$36.68	$0.019	$0.006
Total cost of installation of 20-inch Class C pipe, 1 955 m. = 6 414 ft................		$30 364.51	$15.532	$4.734

(Note: Contract price = $19.40 per meter.)

Throughout the design and construction of these water works, Mr. Pompeyo Sariol was chief of the Department of Public Works for the Province of Camaguey; the writer, chief engineer of the water-works department; Mr. Earle K. Knight, resident engineer for work outside the city; and Mr. John E. Shoemaker, resident engineer for the city distributing system.

THE POUGHKEEPSIE WATER WORKS.

BY DR. JOHN C. OTIS.

[*Read September 9, 1909.*]

The commissioners appointed by " an act to provide for a supply of water in the city of Poughkeepsie and for sewerage therein," in their report dated February 7, 1870, state that they called to their aid James P. Kirwood, Esq., well known for his abilities as a consulting hydraulic engineer, and that they also engaged the services of Theodore W. Davis, Esq., as resident engineer.

The investigation of a source of supply covered every available creek, including the Hudson River, Fallkill Creek, Crum Elbow, and the Wappingers Creek.

The report of Chief Engineer, Mr. J. B. G. Rand, on the river supply is quite interesting, especially his footnotes in reference to the word " sewage " in the text when speaking of the sewage contamination in the river. This I present here to show plainly what was in the mind of the engineer in 1870 and before.

" The evils resulting from the domestic use of water contaminated with sewage are too well known and of too disagreeable a character in contemplation to admit of much discussion. A regard for the decent taste of the people would prevent us from taking the water from any source which had received sewage, and might, therefore, contain the living germs of cholera, typhoid fever, dysentery, tape worm, etc., without using every reasonable means to guard against distributing them. It is true, the volume of water in the river is so large compared to the quantity of human excreta discharged into it that not much harm can come by this discharge at present. But who can say how much water and how much time is required to destroy these germs; or how much harm may come?—the ablest scientific minds are unable or unwilling to answer. It is, however, well settled that numerous cases of the above diseases have been directly traced to the use of water polluted by sewage, and that, in other cases, the type, though changed, is the effect of such water."

It was finally summed up that the advantages of the river system were a never failing supply and the securing of a better fire

protection, while the objections were contamination by sewage, which would be a constantly increasing evil unless stopped by the enactment and enforcement of laws, the quantity of other foreign matter brought down the river, the saline matter at times, and the annual outlay for pumping.

It was finally decided to utilize the Hudson River as a source of supply and the water-works arrangement settled upon in 1871, and later installed, consisted of a pumping station at the river, a filter, a force main to a reservoir on College Hill, and a distribution system.

The pumping machinery, made by H. R. Worthington, of New York, consisted of two pumping engines with boilers. One engine, the smaller, a high or low pressure duplex steam pump working under a lift of 10 ft. and against a head of 20 ft., supplied water to the filters. The large engine, a compound duplex condensing pump, working against a lift of 9 ft. and a head of 270 ft., furnished filtered water at the College Hill distributing reservoir.

The contract for the purchase of these engines provided for a duty test of 500 000 ft. lb., and it is stated that their performance exceeded this specification.

The filtering works consisted of a raw-water basin 25 by 60 ft. and 12 ft. deep, in three compartments arranged in reference to the deposition of the heavier particles of mud. The two uncovered filter beds were each 200 by 73½ ft., giving 14 650 sq. ft. of filtering area with a depth of 6 ft. of filtering materials as follows:

24 in. of sand.
6 ,, ,, ¼-in. gravel.
6 ,, ,, ½ ,, ,,
6 ,, ,, 1 ,, ,,
6 ,, ,, 2 ,, broken stone.
24 ,, ,, 4 to 8 in. fragments.

This large open filter, with which filtration was started, continued as originally constructed to do the work for the city until 1895, in which year the question of enlargement of filtering area was agitated. It was set forth to the Common Council, from which body funds were sought, that in April, 1895, for four successive times in one month, the city's storage of water was exhausted, due

to the heavy rains causing the raw water to be charged with an unusual supply of red mud and silt which clogged the beds, permitting only four and one-half day runs between cleanings. This, with the difficulties met in cleaning in the winter, brought the officials to the point of feeling the necessity of additional area.

The new filter bed consisted of a single basin having an area equal to that of both basins comprising the old bed, thus doubling the area.

The form of construction is described in the report of 1896 as follows:

The length of this basin inside of wall is 260 ft.; width, 114 ft.; total area, 29 640 sq. ft. The clear depth of the basin from the top of the coping to the surface of the concrete bottom is 10.3 ft. The side walls, except along the old basin, consist of rubble masonry laid in Rosendale cement mortar, faced with a brick wall laid in Portland cement mortar. The inner faces of the walls are vertical. The bricks used for the facing were Catskill shale paving brick, of the best quality, absorbing not over 2 per cent. by weight of water after twenty-four hours' immersion. The thickness of these face walls for two thirds the height from the bottom is 18 in., and the remainder, 13½ in. On the west side, along the old basin, buttresses projecting from its walls necessitated filling between them with brick masonry. This was done with second-class bricks of the same kind, laid in Portland cement mortar. The whole was faced in the same way as the other walls, 13½ in. thick.

The bottom of the excavation varied from soft muck to solid rock. The rock was leveled and the muck excavated, the excavation being filled with fine cinders well rammed. The entire area was covered with concrete of Rosendale cement, 12 in. thick, put on in two layers.

A main drain, of brick masonry, sunken below the surface of the concrete, extends longitudinally along the center of the basin from south to north. Lateral drains of 6-in. tile pipes are laid on the concrete bottom at right angles to the main drain, and 10 ft. 3 in. apart between centers. These lateral drains are covered with 2-in. broken stone. The spaces between the laterals are filled to a depth of 10 in. with 2-in. broken stone and 1-in. gravel. Above this is a layer of ½-in. gravel 8 in. thick, and above this a layer of

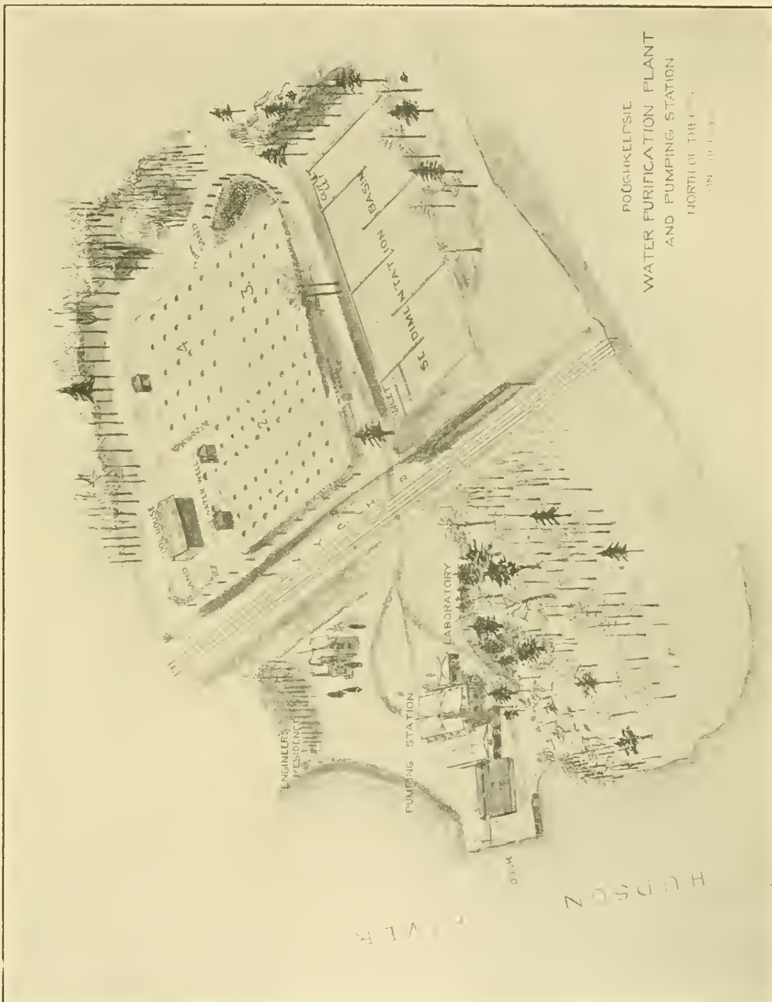
$\frac{1}{4}$-in. gravel 6 in. thick, the total thickness of the gravel layers being 24 in. Above the gravel is the bed of filtering sand 31 in. thick. The water for this bed is taken from the inlet basin of the old filter bed, through an 18-in. supply pipe, entering the basin at the center of the south wall, and discharging into a distributing well 2 ft. wide, extending entirely across the south end of the basin. The top of the inner wall of this well is of the same height as the surface of the sand, and is perfectly horizontal, so that the water in entering the bed shall produce as little disturbance of the sand surface as possible.

The main drain discharges into a delivery well 6 ft. by 8 ft. on the outside of the north wall of the basin. In this well is a weir of cast iron sliding in vertical grooves, by means of which the working head may be regulated.

From the delivery well a 24-in. cast-iron pipe conveys the water westerly to a circular delivery pipe well, north of the clearwater basin of the old filter bed, at the bottom of which is a 6-in. valve opening into a short pipe connecting with a 20-in. drain. From this delivery pipe well an 18-in. cast-iron pipe conducts the water south to the clearwater basin of the old filter basin. In this last pipe is a valve, and also one in the supply pipe, by means of which the bed may be cut out of service at pleasure. The construction of the basin was done under contract by Charles Cook, of this city. The gravel and sand, comprising the filtering materials, were delivered under contract by John Sutcliffe, of this city, at the walls of the basin, and were placed in position by day labor. The gravel and sand were obtained by Mr. Sutcliffe at Heamstead Harbor, Long Island, and were thoroughly washed at the banks.

In 1904, there was an agitation to reconstruct and cover the filters. The reasons given for making the change were, low purification efficiencies, expense of removing ice, leakage in old filters, and growth of algæ on the beds. The work was started, and is described as follows:

The work done consisted in removing all the filtering materials from both filters; and, for the old or west filter, placing a puddle filling in the bottom of both sections; placing a concrete floor in the form of inverted arches on this puddle; lining the side walls with concrete; setting concrete piers; covering the whole with groined



AN ISOMETRIC VIEW OF THE PURIFICATION PLANT.

arches of concrete, with 2 ft. of earth cover; and providing and placing new under drains. In the new or east filter the work consisted in covering the old concrete bottom with a waterproof coat of asphalt, laid on hemp burlap; laying upon this asphalt coat a concrete course, in the form of inverted arches; building a central transverse wall of concrete; placing concrete piers, and covering the whole with groined arches of concrete with 2 ft. of earth cover; modifying the main drain and replacing old laterals. The sides and bottom of the clearwater basin were also lined with concrete, and concrete piers and arches with earth cover were placed. This system as completed in 1905 consisted of four units of $\frac{1}{3}$ acre each.

The period from the construction of the filters to 1880 was one of absolutely no particular control and no regularity of operation. It was not unusual to allow the filters to remain out of commission for a whole winter season. The typhoid death-rate statistics check out these periods very nicely.

The period from 1880 to date has been one of more intelligent control, during which time no unfiltered water has been served to the consumers, but without doubt there have been times when it has been hard to draw the line between the filtering of water and the screening of it.

TABLE 1.

TYPHOID FEVER STATISTICS.

Year.	Total Deaths.		No. of Cases.	Per Cent. of Typhoid Deaths to Cases.
	Typhoid.	Malarial.		
1893	21	10	61	33.0
1894	14	6	28	50.0
1895	10	8	27	37.0
1896	5	4	32	15.6
1897	10	5	19	52.5
1898	5	2	20	25.0
1899	6	3	52	11.5
1900	11	3	51	21.5
1901	10	1	63	16.2
1902	5	3	33	15.1
1903	11	2	39	31.0
1904	15	2	93	16.1
1905	9	2	78	11.5
1906	9	3	66	13.6
1907	30	3	168	18.0
1908	11	..	42	26.2

Typhoid and intestinal diseases have been prevalent in the city, and the statistics from our health department do not begin to show what has happened. Table 1 shows the number of deaths from typhoid and malarial diseases for each year, from 1892 to date; also the number of cases reported by the health department, and the per cent. of deaths to cases. This percentage varies from 52 per cent. to 11.5 per cent., showing clearly the very low average ability of the physicians or great lack of accuracy in reporting. The table shows that while malarial diseases are beginning to disappear, the typhoid cases have increased, as we become more enlightened in the management of filters and their design. Such inconsistent results must be due to erroneous statistics. Just a few years ago, the health department would accept no case as typhoid unless a positive Widal reaction was obtained, while at this time any fever or intestinal disease is reported as typhoid.

The Hudson River water in its raw condition is most variable. This great river comes to us and by us at the salt line, and in about every twenty years the taste of salt is perceptible in the filtered water. In the fall of 1908, it was so salty that it was most unpleasant to drink. This of course occurs during seasons of extreme droughts. The water varies in color, in turbidity, and in purity with the change of the tide, with the weather, and with the time of day; it may be heavily laden with silt or entirely free from it; it may be very impure when filled with silt or it may be a fairly good water; it may be perfectly clear and yet be so polluted that it is suicide to touch it to your lips.

A sedimentation basin was added to the plant, being finished in December, 1907. This basin started in operation on December 29, 1907, and continued until June 11, 1908, when it was emptied, the water being clear enough without its use, and also to do away with the growth of algæ.

Coagulation with alum was used, with the exception of three weeks, until May 22. This interruption, from January 27 to February 18, was due to the clogging of beds owing to inexperience in operation. The alum was added to the raw water through the suction pipe of the low lift pump from an alum tank in the chemical laboratory, the amounts varying with the turbidity from $\frac{7}{8}$ grains per gallon with a turbidity of 25, to $2\frac{1}{2}$ grains per gallon with a

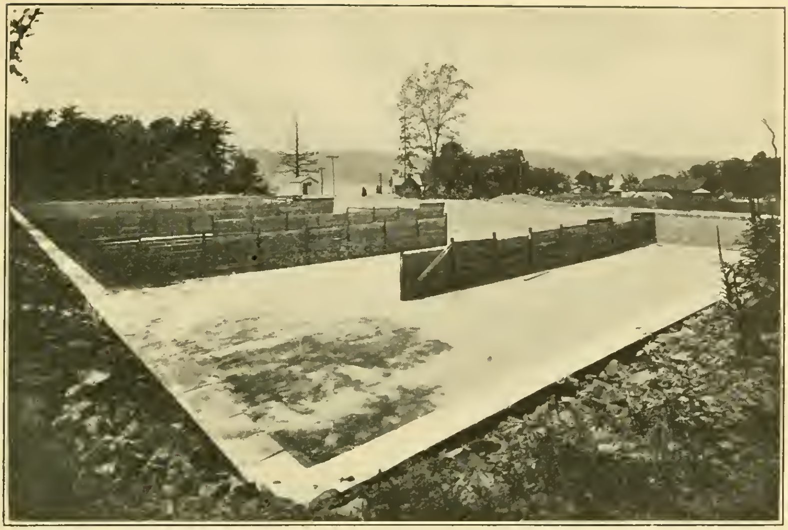


FIG. 1. THIS COAGULATING BASIN HAS A CAPACITY OF 3 MILLION GALLONS. THE DISINFECTANT HOUSE CAN BE SEEN AT THE FARTHER CORNER. THE TOP BOARDS OF THE BAFFLES WERE REMOVED BY ICE.

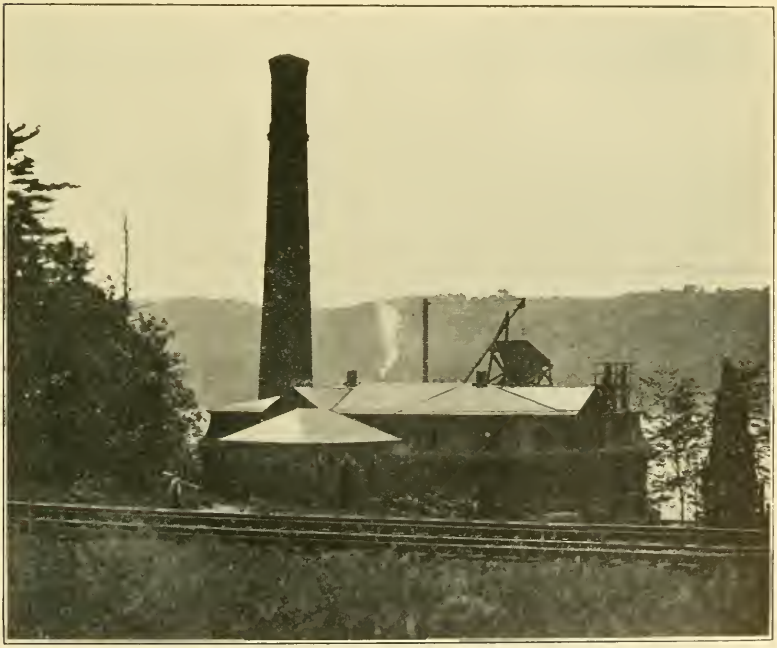


FIG. 2. PUMPING STATION AND CHEMICAL LABORATORY.

TABLE 2.

General Summary of Bacteriological Results. Monthly Averages.

Month.	Raw Water.		Settled Water.				Effluent Filter No. 1.				Effluent Filter No. 2.				Effluent Filter No. 3.				Effluent Filter No. 4.				Remarks.
	20°	37°	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	20°	Per Cent. Rem.	37°	Per Cent. Rem.	
1907.																							
December	11 400	....	....	....	....	....	108	99.1	....	....	119	99.0	....	....	89	99.2	....	....	82	99.3	....	....	Cd. basin not completed.
1908.																							
January	9 200	....	6 920	24.8	....	....	88	99.0	....	....	104	98.9	....	....	69	99.3	....	....	63	99.3	....	....	
February	19 520	....	16 300	16.5	....	....	130	99.3	....	....	96	99.5	....	....	142	99.3	....	....	106	99.5	....	....	Coagulant not used.
March	20 600	....	5 440	73.6	....	....	104	99.5	....	....	125	99.4	....	....	76	99.6	....	....	94	99.5	....	....	
April	16 420	....	6 560	60.0	....	....	47	99.7	....	....	47	99.7	....	....	44	99.7	....	....	57	99.7	....	....	Coagulant in large quantities.
May	9 790	1 110	5 390	44.9	750	32.4	26	99.7	22	98.0	30	99.7	18	98.4	36	99.6	30	97.3	38	99.6	22	98.0	
June	3 290	385	2 970	09.7	230	40.3	28	99.1	17	95.6	27	99.1	16	95.8	28	99.1	12	96.1	50	98.5	14	96.4	No coagulant.
July	2 120	445	....	....	....	....	25	98.8	18	96.0	70	96.7	23	94.8	17	99.2	11	97.5	25	98.8	41	90.8	Basin not operated.
August	2 000	730	....	....	....	....	21	99.0	9	98.8	22	98.9	12	98.4	27	98.7	14	98.1	29	98.6	19	97.4	
September	2 090	780	1 080	48.3	535	31.4	18	99.1	8	99.0	42	98.0	30	96.2	16	99.2	15	98.1	18	99.1	16	98.0	No coagulant.
October	2 160	870	1 250	42.1	450	48.3	24	98.9	13	98.5	12	99.5	11	98.7	20	99.1	12	98.6	31	98.6	28	96.9	No coagulant.
November	2 060	705	1 400	32.0	405	42.4	16	99.2	11	98.3	14	99.3	10	98.4	24	98.8	10	98.4	25	98.8	41	94.0	Coagulant used 3 weeks.
Average	8 390	720	5 260	*40.6	475	*38.3	53	99.4	14	98.1	59	99.3	17	97.6	49	99.4	15	97.9	52	99.4	26	96.4	
December	8 070	454	7 040	12.8	248	45.4	94	98.7	7	97.3	108	98.5	10	96.0	86	98.8	9	96.5	107	98.5	9	96.5	
1909.																							
January	11 690	399	5 690	51.4	135	66.2	177	97.1	16	88.1	218	96.4	21	84.5	171	97.1	19	85.9	164	97.2	16	88.2	
February	32 640	709	1 210	85.2	107	84.9	114	90.6	15	86.1	149	87.8	17	74.6	109	91.1	15	86.0	96	92.1	11	89.7	
March	30 000	539	497	98.3	84	84.5	69	86.2	11	86.9	47	90.5	15	82.1	37	92.5	9	89.3	48	90.4	10	88.2	
April	13 520	331	70	99.7	49	85.2	16	77.2	10	79.7	14	80.1	16	67.4	14	80.1	11	77.5	22	68.5	12	75.6	
May	3 222	179	118	96.3	25	86.1	38	67.8	15	60.5	19	74.3	13	48.0	18	84.8	11	56.0	22	81.4	11	56.0	
June	1 953	326	413	89.2	85	74.0	25	94.0	12	85.9	17	96.0	9	89.5	15	96.5	8	90.7	14	96.7	7	91.9	
July	1 475	475	393	80.1	209	56.1	16	96.0	8	50.0	17	95.7	9	95.7	13	96.7	7	96.7	17	95.8	8	96.3	

* Per cent. removal in basin computed from average of months when in operation.

Average bacteria in effluent for 1908, 20°—53, 37°—18.

Average per cent. removal for 1908, 20°—99.4, 37°—97.5.

turbidity of 500. This method of sedimentation and coagulation in connection with the Hudson River water is simple and efficient when the water is bad and heavily laden with silt. The basin in its first run gave efficiencies good enough to give a uniform water to the filter, and the alkalinity permitted large amounts of alum. The maximum bacteriological efficiency obtained was 98 per cent.

Table 2 shows the record of operation of the purification plant. This table gives the monthly averages of raw, settled, and filtered water for the 20° and 37° counts and are averaged from daily examinations with two plates to each count with an incubation of sixty-five hours.

As shown in Table 1, the operation of this plant reduced the typhoid cases from 168 in 1907 to 42 in 1908.

Table 3 gives the quantities of alum used, the amount of water treated, and the percentage monthly removal of turbidity with alum during the last winter.

TABLE 3.

Coagulation Record.

	No. Days.	Average Lbs. Used per Day.	Average Million Gallons of Water Pumped per Day.	Grains per Gallon.	Turbidity.	Turbidity after 24 Hours.	Per Cent. Rem.
1908–1909.							
December	18	393	3.199	1.11	20.0	13.5	32.5
January	30	767	2.728	1.61	32.5	18.5	43.
February	9	631	2.88	1.77	163.3	25.5	78.2
March	12	748	2.94	1.81	98.6	28.1	71.5
April	16	589	2.72	1.53	55.5	23.7	57.3
May	2	551	2.97	1.31	17.0	13.0	24.7

The summer of 1908 was extremely dry for New York state, and the Hudson River became very low, the salt water reached Poughkeepsie in the fall and was noticeable in the drinking water from the middle of October to the middle of November, for the drought continued into the winter. The river froze over and the water came to us concentrated with sewage, but with no turbidity. As there was nothing in suspension, no results were obtained from the

sedimentation basin nor from the alum. To add to this condition the filters failed to respond to any treatment, and as a result, there were bacterial counts in the filtered water.

Mr. G. C. Whipple was called in consultation and he suggested that "chloride of lime" be applied instead of coagulant.

This was done at once with most satisfactory results. The application was begun February 1, using the coagulant apparatus, which introduces the chemical into the low lift pump suction line. By February 12, a temporary dosing appliance (consisting of two barrels with a suitable "regulating box") was constructed to apply the chloride at the inlet of the sedimentation basin, and the permanent apparatus was put in operation on March 17. This consists of two wooden tanks of about 1 100 gallons capacity each, and a regulating box, one tank being used while the other is being filled. The regulating box is a lead-lined chamber 18 in. by 18 in. by 12 in. with a ball-cock on the inlet and a small hand valve on the outlet. Lead and bronze are used throughout in the piping and valves. The tanks are hand stirred at frequent intervals, but this does not insure absolute uniformity of applied solution, the variation amounting to 10 per cent. or 15 per cent. at different times. Other means of stirring are being considered. The strength of solution is 20 to 35 lb. of chloride to a tank (about a 20 per cent. to 35 per cent. suspension). A much stronger liquor, about 25 per cent., was used in the barrel apparatus described before, but much trouble was experienced by reason of clogging of valves and consequent interruption. Electrolytically prepared bleaching powder is used, analyses of which show from 37 to 39 per cent. by weight of available chlorine. The average amount applied has been about 0.4 parts of chlorine per million.

Amounts less than 0.2 parts have been tried experimentally, but with marked decrease in per cent. of bacteria removed.

The following table shows the bacteria removal obtained.

Applied Chlorine. Parts per Million.	Bacteria in Raw Water.	Bacteria in Settled Water.	Per Cent. Removed.
.25	12 600	1 160	90.8
.25–.40	41 200	1 100	97.3
.40–.50	18 700	165	99.1
.50	50 400	234	99.5

These results are not entirely conclusive evidence that somewhat smaller doses applied carefully would not do the work. The reliability of the results of earlier experiments with small amounts was impaired by annoying interruptions incident to starting new and unfamiliar apparatus, and because coagulant was used part of the time to treat the turbidity and color. Experiments using quantities up to .80 parts per million did not show a material increase in percentage removed.

The bacterial content of the filtered water averaged by weeks was as follows:

Week Ending	Bacteria per Ccm.	Week Ending	Bacteria per Ccm.
February 6	185	March 20	80
,, 13	100	,, 27	32
,, 20	120	April 3	23
,, 27	75	,, 10	16
March 6	30	,, 17	16
,, 13	60		

showing a progressive decrease of bacteria in the filtered water. On several occasions in the first weeks the bacteria content of the filtered water was higher than in the settled water applied to the beds.

The following tables show the results of tests for B. coli:

RAW WATER.

Quantity Ccm.	Number of Tests.	Number of Positive Tests.
.01	4	2
.1	4	1
.5	5	3
1.0	3	3

SETTLED WATER.

Quantity. Ccm.	Number of Tests.	Number of Positive Tests.
1	16	2

FILTERED WATER.

Quantity. Ccm.	Number of Tests.	Number of Positive Tests.
2	4	0
3	55	3
5	8	0

FIG. 1. COLLEGE HILL RESERVOIR.—12 MILLION GALLONS CAPACITY.

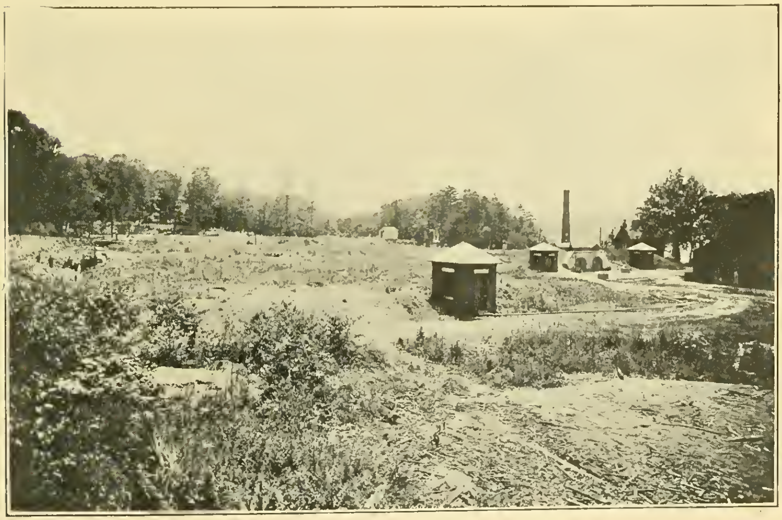


FIG. 2. GENERAL VIEW OF THE PURIFICATION PLANT.

The presence of free chlorine in the settled and filtered water was determined by the tolidine test recently invented by Professor Phelps of the Massachusetts Institute of Technology. This is the most sensitive test for free chlorine known. The distinctive color resulting when free chlorine and this reagent are brought in contact has been observed at the laboratory of the Poughkeepsie plant when the amount of chlorine was known not to exceed .025 parts per million. The test has frequently given positive results in the settled water, but never has there been the slightest trace in the filter effluent. A slight musty odor has been noticed in the filtered water when the test was made on a hot sample, but no taste or odor can be detected in the cold. There are no records of odor before the use of chlorine, so it is impossible to say whether or not the condition is due to its use.

The cost of treatment by this process is insignificant. The building and tanks cost $275 and are of a substantial nature. No extra employees are required, so the cost is reduced to interest and depreciation on the plant and cost of chemicals. The former is difficult to estimate but should not amount to over two or three cents per million gallons. The cost of the bleaching power is 1.4 cents per pound, bringing the total cost up to 14 or 15 cents per million gallons.

CONCLUSIONS.

It is seems safe to conclude from the experience at this plant during two and a half months operation:

1. That amounts of free chlorine from .35 to .45 parts per million will reduce the bacteria in the sedimentation basin more than 99 per cent. and will practically eliminate the B. coli and presumably the typhoid germs.

2. That free chlorine persists for at least twenty-four hours in the unfiltered water, though very much reduced in quantity.

3. That no free chlorine remains in the water after filtration.

4. That no tastes or odors are developed to such an extent that the consumer notices them.

Table 4 shows quite plainly, when peculiar local conditions are considered, that 0.5 parts per million will give percentages of removal of nearly 100 per cent., when used in connection with alum

TABLE 4.

CHLORIDE OF LIME.

Month.	Hypochlorite. Lb. Used per Day.	Lb. Free Chlorine Used per Day.	Million Gallons Pumped per Day.	Chlorine. Parts per Million per Day.	Bacteria. Per Cent. of Removal.
1909.					
‡February.....	31.4	11.6	2.88	.46	85.2
†March........	28.8	11.0	2.94	.45	98.2
†April.........	32.1	12.4	2.97	.49	99.7
†May..........	23.1	8.8	2.81	.34	96.3
*June.........	20.0	7.1	2.60	.34	89.2
*July..........	31.4	11.1	2.60	.51	80.1

‡ Method of applying not satisfactory.
†Twenty-four hours' storage before taking samples.
* Six hours' chlorination.

In order to bring out more forcibly the necessity for some radical action, it may be seen by referring to bacteriological records for 1908 (Table 2) that the summer and fall averages were very low, and that, of course, there was no typhoid fever. In December, the counts in the filtered water ran higher, reaching to 450, causing unusual alarm, although throughout the entire month of December no typhoid was reported. Table 5 shows the daily average number of bacteria for four filters for each month, beginning with December, 1908, together with the number of typhoid cases reported, every one of which was specially investigated. The third column shows the number of cases which may have been caused by the city water, which checks out with the condition of the water in December, January, and February, and which condition was remedied by chlorination.

The total number of cases of typhoid for nine of the twelve months is 23 for 1909 to 41 for the corresponding months of 1908.

TABLE 5.

TYPHOID TABLE.

Months.	Average Number Bacteria in Filtered Water.	Number of Cases of Typhoid Reported.	Number of Cases Possibly Caused by City Water.	Number of Cases for which Definite Cause was Found.	Number of Cases which from General Conditions or Peculiar Circumstances may be from Some Other Source than Water.
1908.					
December.......	99	0	0	0	0
1909.					
January........	182	7	3	3	1
February.......	117	7	3	3	1
March..........	50	3	2	1	..
April..........	16	2	1	1	..
May............	24	1	..	..	1
June...........	18	1	..	..	..
July...........	16	2	1	..	1

We have recently established a price for water which, with our thoroughly metered service, will furnish income to meet all obligations and care for the interest and liquidate the bonded debt in thirty years.

The total receipts from the sale of water from 1873 to 1908 inclusive amount to $1 077 643, ranging in amounts yearly of from $9 000 to $50 000. The operating expenses during this same period amount to $866 536.04.

The additions to the distribution system have amounted to $94 550.53; the renewals and changes as follows: For new pumps in 1893, $35 689.95; filter improvement, $80 830.27; new intake, $6 135.41; and $40 407.37 in the construction of a new sedimentation basin, amounting in new construction, including the extension of the distribution system, to $257 613.53. The original bonded indebtedness of the city for its water works was $550 000, which was the original cost. These bonds were 7 per cent., interest bearing. During thirty-seven years, $35 000 worth of bonds have been paid, although many have been refunded at lower rates of interest. Forty thousand dollars was added in 1907, leaving the present bonded indebtedness at $555 000. A rough computation

shows that there has been paid about $1 080 000 in interest, all of which came out of the general city fund.

There were delivered in this thirty-seven years 22 000 million gallons of water at an average cost for operating expenses of 3.5 cents per thousand gallons.

The cost per thousand gallons for new construction amounted to 1.1 cents.

The city has been paying for the use of money at the rate of 4.8 cents per thousand gallons.

The total cost of the city to provide water amounts then to 9.5 cents per thousand gallons.

The total receipts per thousand gallons amount to 4.8 cents, showing that the receipts have been about one half the cost.

DISCUSSION.

A Member. I should like to ask Dr. Otis what the present population of Poughkeepsie is.

Dr. Otis. The present population is about 30 000. It has gone up from 18 000 to 30 000 since the installation of our water works, and the Board of Trade will tell you that we expect soon to have 50 000.

Mr. Alexander Potter.* May I ask Dr. Otis if he has any special reason for his conclusion or his suggestion as to the abandonment of the sand filter as the matter has been worked out in Poughkeepsie.

Dr. Otis. I should like to have it distinctly understood that that is a suggestion coming from a layman, and, therefore, is not one that carries any special weight. I base my conclusions simply on a study of the statistics of our filter plant. So long as we were using sand filtration alone we did not produce a good water. Our water for most of the time was really much worse than our records show, from the fact that when we awoke to the necessity of a change we found that we had been using in our bacterial analyses a gelatine which was not correct, so that undoubtedly our counts should have been at times much higher than our records show. I simply put it as a suggestion from an ignorant layman, upon a

* Consulting Engineer, New York City.

study of the statistics, that we possibly would have just as good water simply by the use of our settling basin and our coagulant. I assume that sooner or later we will know more about the chemical treatment of water, and I believe it is only a matter of a short time when we shall know a chemical substance that will take out all these growths, not only the algæ, but every other growth that is likely to contaminate a reservoir.

MR. EARLE B. PHELPS.* I have been much interested in Dr. Otis's remarks about disinfection, as I have made that particular point of water purification a special study for the past few years. I fully agree with what Dr. Otis has said as to the experimental stage with regard to water disinfection. I have the firmest belief in the great possibilities of some such method, but whether bleaching powder or some other similar oxidizing agent is more efficient remains for the future to determine.

There are some points in connection with this matter, however, which I think cannot be overstated. The chief of these is that I believe we should insist continually on the fact that disinfection is not a substitute for filtration. It is an adjunct, apparently, which permits us to filter the water at higher rates, and which gives us a greater margin of safety and greater security against a breakdown of filtration.

But there are constituents in a polluted water which disinfection does not remove, things other than germs which it is undesirable for many reasons to drink, which common sense tells us not to drink, and which, whatever may be the scientific aspects of the case, we simply do not want to drink. Personally, I am firmly convinced that the studies of Mr. Allen Hazen and Professor Sedgwick have shown us that there is an actual danger in these polluting substances. Aside from the bacteriological diseases carried by water, I believe that there is a detriment in polluting material which probably acts indirectly by lowering the general vitality. Observations show that we have from this cause an increased deathrate among diseases which we cannot ascribe to actual bacteriological infection.

In any discussion of disinfection methods, I think we should not

* Bacteriologist and Chemist, Sanitary Research Laboratory, Massachusetts Institute of Technology.

lose sight of the possibilities of ozone. Ozone has a poor record at present, but it must be remembered that ozone has successfully passed through the experimental stage through which these newer compounds are now passing. Ozone has hitherto failed not from any inability to purify water, but for mechanical reasons. We cannot produce ozone at a sufficiently low price. As it is a matter of mechanical and electrical engineering, there is no reason to believe that ozone must always be as high in price as it is to-day. There is every reason, on the contrary, to expect that ozone machines will be developed, and I believe they are being developed, which will make ozone a practical disinfectant; and once given ozone at sufficiently low cost to make it possible to be used, it is certainly the ideal disinfectant. As ozone reduces to ordinary oxygen, there are absolutely no after effects, so there can be no objection to its use. This is a very practical matter to be considered.

There are certain objections to the use of chloride of lime which seem to have some weight. It has been observed in some places, and I was interested to note that Dr. Otis referred to the matter, that the odor of the water is slightly altered and made a little unpleasant by the addition of bleaching powder. I have studied that point and am convinced that it is not due to the oxidizing action of the chlorine but to "chlorination," as the chemists call it; that is, to the action of the chlorine upon the organic material accumulated in the sand. The sand is there to accumulate the organic material, and if we get these odors when we pass the chlorine through it, then some other procedure is necessary. Adding the chlorine after filtration may be the solution of this problem.

There are certain other objections to the use of chlorine compounds for which there may be no real scientific reason, but which are nevertheless forcible in the public mind. For this reason, while we have in the case of bleaching powder a disinfectant of very great value, and while the use of this disinfectant probably works no harm so far as we know, it would be highly desirable to substitute some other disinfectant which might at least have a better sounding name. In this connection I have been investigating for some time the disinfecting properties of the various peroxides, in-

cluding the peroxides of sodium, calcium, and magnesium. At the present market prices of these substances none of them are practical for water disinfection. The magnesium peroxide is the most advantageous for use, since this forms in the water hydroxide of magnesium, which appears to be fully as efficient as the aluminum compound as a coagulant. The magnesium salt is also sufficiently soluble for use. The calcium peroxide, on the other hand, is very slightly soluble and could only be used in conjunction with sand filters, in which case a layer of the undissolved peroxide would accumulate on the sand. The water in passing through this layer is efficiently disinfected. Peroxide of sodium acts too violently with the organic matter to be economical. In the presence of any considerable amount of organic matter it is rapidly decomposed and is a most efficient oxidizing agent, but larger quantities are necessary to produce bacterial results than of the other compounds mentioned.

Since the cost of production of all of these substances is largely a mechanical question and depends also, in some degree, upon the market demand, it is not at all improbable that, given sufficient incentive, the manufacturers may be able to produce them in large quantities at a price which would make their use possible. It is believed that in some of these compounds, particularly the magnesium peroxide, we have a most valuable adjunct to filtration.

In my opinion, the chief line of development of the disinfection methods lies in connection with rapid mechanical filtration. Slow sand filters reach their limiting rates when color and turbidity as well as bacteria begin to come through, and in most cases the passage of bacteria through the filter is coincident with the passage of other impurities. On the other hand, with mechanical filters using coagulants the rate is only limited by the necessity for bacterial removals. If such removals can be accomplished in the final disinfecting treatment, the present rates of mechanical filters can undoubtedly be doubled without sacrificing efficiency in other lines.

In brief, then, I regard these recent developments in the disinfections of water as most important in the sense that they will make it possible to operate mechanical filters at high rates, to relieve the burden of many filters which are now overworked, and

to reduce by nearly 50 per cent. the cost of new works. If such proves to be the case, we may expect to see plants built where polluted raw water is now being used, and a general improvement in the quality of water delivered by many plants which are now greatly overworked.

A MEMBER. Bleaching powder sterilizes and practically embalms the bacteria, doesn't it?

MR. PHELPS. I cannot call it embalming; it kills them.

A MEMBER. Have you tried any tests to determine whether they are actually killed or whether they would come back again after a length of time.

MR. PHELPS. Those germs which are actually killed do not come back, but if I catch the point of the question it refers to the secondary increase in bacteria which is often observed after disinfection. The few residual germs which are present may grow, and often do grow, so we get an increased count of a secondary kind. From a sanitary point of view, however, that does not mean anything. We have become accustomed to considering high counts as an indication of pollution; but after we have killed out the disease germs it does not make any difference if the other germs grow, so we pay particular attention to the disease germs, using the B. coli as an index, and if we get those down we are not worried by any subsequent growth which may occur in the reservoir.

MR. EDWARD BARTOW.* I should like to ask either Dr. Otis or Mr. Phelps whether they have any definite knowledge of detrimental results from the use of the amount of bleaching powder ordinarily used. Mr. Phelps suggests other disinfectants, and I thought possibly he had in mind some definite detrimental effects of bleaching powder. He suggests also the possibility of a controversy, perhaps something like the alum in baking powder controversy, which may arise concerning bleaching powder, and I should like to know whether there is any ground for any such a controversy.

DR. OTIS. I should like to say, in regard to the Poughkeepsie filters, that we have had no subsequent bad results. In fact, we have never found any chlorine in our filtered water.

* Director State Water Survey, Urbana, Ill.

Mr. Phelps. I regard the possible ill effects as imaginary rather than real, but there seems to be in this respect a wide gap between the practical water-works men and the people who consume the water, and we all know how easy it is for a line of kicks to get started at the water-works office when some suggested change has been published before the change has been brought about. The kind of thing I have in mind is merely that popular clamor which we all know the force of, however ill founded it may be.

DISINFECTION AS AN ADJUNCT TO WATER PURIFICATION.

BY H. W. CLARK AND STEPHEN DE M. GAGE.

[*Read September 9, 1909.*]

At the time of the last New York convention of this Association, 1905, the discussion of the use of copper in water supplies was at its height, and one of the meetings was given over to a symposium upon this subject. Recently, the use of hypochlorite of lime or bleaching powder for the disinfection of water has come to public notice through the litigation which followed its use in one of the large water supplies in New Jersey, and bleach treatment has been tried out in a number of places. Extensive studies of disinfectants in connection with water and sewage purification have been in progress at the Lawrence Experiment Station for a number of years, and much has been learned concerning both the effectiveness and the cost of such treatment. Of the many disinfectants tested, the copper salts, the permanganates, and the hypochlorites are the only ones which have shown any promise of usefulness in water purification, and it is with the last two that this paper has to deal, the copper results having already been discussed at the former meeting. The action of hypochlorites and permanganates in water are quite similar; both are oxidizing agents, and it is to this oxidation that their disinfecting action is due. Unlike copper salts, neither of them retains its identity for any length of time in the water, and the slight increase in the permanent hardness caused by the amounts of bleach ordinarily used in water purification, or the small traces of manganese which may remain in solution after permanganate treatment, cannot have any possible physiological action upon the consumer.

There are two views which may be taken of the disinfection of water. In one, absolute sterilization is aimed at, that is, the complete removal of all bacteria is considered necessary. Another view is the removal only of such a proportion of the bacteria that

a water may be made to compare in bacterial content with waters ordinarily considered safe. This latter is the more general view and applies to the use of disinfectants, either in combination with, or as a substitute for, some form of filtration. In the experiments here described, both views have been considered. In one set of experiments, it was attempted to determine how much of each of the disinfectants would be required to produce a safe water as judged by our usual bacterial standards, and also how much would have to be added to obtain a water which was absolutely sterile. In another set of experiments, the disinfectant was applied continuously to water as it passed through a reservoir, the aim being to keep the proportion of disinfectant as low as possible and still obtain an effluent of the same bacterial quality as the effluents from our best water filters. In one of these latter experiments, Merrimac River water was partially clarified before disinfection by passing it through a roughing filter of coarse sand at a high rate, and in the other, the disinfectant was added to the raw water together with coagulants before passing it through a mechanical filter.

DISINFECTION WITH PERMANGANATE OF POTASH.

The fact that the numbers of bacteria in water are considerably reduced by the use of permanganates has been known for many years, and the permanganates of potash, of soda, and of lime have been employed to a limited extent in a number of places. During the Boer war, potassium permanganate was used to disinfect drinking water for the British troops in the field. At Blœmfontein, South Africa, permanganates have been added to the water as it enters the storage reservoir for some years. The details of the treatment are not at hand, but removal of organic matter, color, and bacteria are said to be quite satisfactory. The use of permanganates for the removal of color and iron was investigated at the Lawrence Experiment Station, in 1900, as stated on page 462 of the Report of the Massachusetts State Board of Health for that year. The results of the process were not particularly satisfactory with the water studied.

During the past two years, many experiments have been made to determine the disinfecting power of potassium permanganate

when added to water in various proportions. In these experiments different amounts of potassium permanganate were added to the water in bottles, analyses being made immediately, after six and twenty-four hours, and then daily for a number of weeks. A complete sterilization of the water was not effected in any of these experiments, even when the action was continued for many days. Over 98 per cent. of the bacteria were eliminated by treatment with 0.5 parts per 100 000 for from four to six hours. Larger amounts of permanganate, or a continuation of the action for longer than six hours, did not result in any further appreciable decrease in the numbers of bacteria. The reduction in numbers of bacteria growing at body temperature was only 50 to 75 per cent., and considerable numbers of these types of bacteria, including many B. coli, were found in a majority of the samples after treatment.

The cost of treatment with 0.5 parts permanganate ($KMnO_4$) per 100 000 would be from three to four dollars per million gallons. Permanganate treatment may have some value as an emergency measure for preparing drinking water in the field, but on account of its small efficiency and high cost, its use for disinfection of municipal water supplies will always be limited. The results of two representative experiments on the treatment of Merrimac River water with permanganate for six hours are shown in Table I.

TABLE I.

NUMBERS OF BACTERIA PER CUBIC CENTIMETER IN MERRIMAC RIVER WATER AFTER TREATMENT FOR SIX HOURS WITH VARIOUS AMOUNTS OF POTASSIUM PERMANGANATE.

$KMnO_4$. Parts per 100 000.	March 1.			March 15.		
	At Room Temperature.	At Body Temperature.		At Room Temperature.	At Body Temperature.	
		Total.	Red.		Total.	Red.
0.0	1 700	85	52	17 100	65	15
0.5	29	28	3	39	90	4
1.0	31	18	0	36	40	8
1.5	38	26	0	19	40	5
2.0	26	21	0	18	38	4
2.5	29	28	0	20	35	23
3.0	27	36	12	13	38	5
3.5	22	65	27	24	35	0
4.0	22	32	0	26	38	8
4.5	24	22	0	23	38	0
5.0	18	44	23	17	26	13

DISINFECTION WITH BLEACHING POWDER.

A large number of experiments were made to determine the effect of various amounts of disinfectant, and the effect of varying lengths of storage after treatment, upon the bacteriological content of Merrimac River water, sewage, and the effluents from many different types of water and sewage filters. In these experiments, the different proportions of bleach were added to the water in bottles, and analyses were made immediately after the addition of the disinfectant, and after intervals of one, two, three, four, six, and twenty-four hours respectively. The results of these experiments show that the disinfecting power of the bleach is exhausted in one to two hours where small amounts are used, but that when large amounts are required, four to six hours or even longer storage is necessary before the action is complete. The results of bleach treatment for one hour in four representative experiments selected from the large number made are shown in Table II.

In general, the treatment of Merrimac River water with 0.1 part per 100 000 chlorine resulted in an effluent corresponding in bacterial quality with the effluents from the best slow sand filters. Much larger amounts are required, however, to produce complete sterilization. In two of the experiments shown, the maximum amount of bleach used, equivalent to nearly 4.0 parts available chlorine per 100 000, was insufficient to produce complete sterilization, although one tenth of that amount caused a bacterial reduction of over 99.5 per cent. and yielded an effluent which was of good quality, judging from the bacteriological data. Similar results are noted in the other two experiments, in both of which a satisfactory purification was produced by bleach equivalent to 0.1 part available chlorine per 100 000. In both of these latter experiments, acid-bacteria growing at body temperature, among which class of bacteria would be included B. coli, were entirely eliminated. Other types of bacteria capable of growing at body temperature, however, were only partially removed by treatment with much larger amounts, in one case bleach equivalent to 2.0 parts chlorine per 100 000, causing a reduction in this type of bacteria of less than 70 per cent. Similar results were common to all of the experiments made.

TABLE II.

NUMBERS OF BACTERIA PER CUBIC CENTIMETER IN MERRIMAC RIVER WATER AFTER TREATMENT FOR ONE HOUR WITH VARIOUS AMOUNTS OF BLEACHING POWDER.

Chlorine. Parts per 100 000.	June 22.			October 22.		
	At Room Temperature.	At Body Temperature.		At Room Temperature.	At Body Temperature.	
		Total.	Red.		Total.	Red.
0.00	3 400	30	12	28 900	130	96
0.38	12	4	0	4	4	0
0.75	15	3	0	8	0	0
1.13	8	2	0	0	2	0
1.50	2	5	0	1	0	0
1.88	0	1	0	0	7	0
2.25	2	0	0	0	7	0
2.63	4	0	0	10	4	0
3.00	0	0	0	0	13	0
3.38	0	3	0	0	18	0
3.75	2	0	0	0	9	0
	November 6.			November 12.		
0.00	14 000	75	14	3 700	81	44
0.10	35	47	0	43	62	0
0.25	32	26	0	46	50	0
0.50	15	35	0	26	30	0
0.75	5	2	0	1	3	0
1.00	2	3	0	1	0	0
1.50	1	26	0	0	0	0
2.00	1	24	0	0	0	0

DISINFECTION IN CONNECTION WITH MECHANICAL FILTRATION OF MERRIMAC RIVER WATER.

In December, 1907, a mechanical filter, containing 24 inches of sand of an effective size of 0.27 millimeter, was put into operation at a rate of 100 000 000 gallons per acre daily, filtering Merrimac River water which had been treated with sulphate of alumina and soda and had been passed through a coagulation and sedimentation basin with a capacity of 3.5 hours' flow. During the first four months of operation, the proportions of coagulants were varied considerably and it was demonstrated that while a fairly satisfactory effluent from a chemical and physical viewpoint could be obtained by the use of sulphate of alumina in the proportion of

0.5 to 1.00 grain per gallon, an effluent containing low numbers of bacteria could be obtained only by the use of about 2 grains of coagulant per gallon. During the remainder of the year, using sulphate of alumina in these proportions, a fairly satisfactory effluent was obtained, although one not as good bacterially at all times as those obtained from sand filters operating at lower rates without coagulants. Beginning December 1, 1908, attempts were made to reduce the cost of treatment by adding only such amounts of sulphate of alumina as were necessary to produce a water of satisfactory appearance, and to reduce the bacteria to a safe limit by adding bleaching powder at the same time as the coagulant. From December 1 to March 15, it was attempted to eliminate the use of soda and to use only so much sulphate of alumina as would be decomposed by the natural alkalinity of the water. This process was found to give unsatisfactory results for the reason that while the natural alkalinity of the water was theoretically sufficient to decompose the alum, owing to the peculiar character of this alkalinity, much of the coagulant was not decomposed. During this period, also, the correct proportion of disinfectant to be applied was determined. After March 15, 1908, soda was added to the water, the soda and bleach being dissolved in the same chemical tank and controlled as a single solution, this having been proved practical by experiments. The results obtained with the combined coagulation and disinfection treatment up to the present time, and the results during the same period of the preceding year when coagulation alone was used, are shown in Tables III, IV, V, and VII. For the purposes of comparison of the two methods, only the five months, April to August in each year, when the filter was in normal operation, will be considered, omitting the earlier months when various changes were being made for experimental purposes. During these five months of 1908, the chemicals used averaged 1.85 grains per gallon sulphate of alumina and 1.50 grains per gallon soda ash. During the same period in 1909, the sulphate of alumina averaged 0.88 grain per gallon; the soda ash, 0.67 grain per gallon, and bleach equivalent to 0.11 part per 100 000 was added. The use of smaller amounts of coagulant during the period of combined disinfection and coagulation resulted in an increase of nearly 25 per cent. in the quantity of water passed through the filter between washings.

TABLE III.

RELATIVE NUMBERS OF BACTERIA DURING MECHANICAL FILTRATION WITH AND WITHOUT DISINFECTION.

	Merrimac River Water.			Effluent from Coagulation Basin.				Effluent from Filter.			
	Bacteria per c.c.			Bacteria per c.c.				Bacteria per c.c.			
	Room Temperature.	At Body Temperature.		Room Temperature.	At Body Temperature.		Per Cent. of 1 c.c. Samples Contain B. Coli.	Room Temperature.	At Body Temperature.		Per Cent. of 1 c.c. Samples Contain B. Coli.
		Total.	Red.		Tot'l.	Red.			Tot'l.	Red.	
1907–1908. Period of Coagulation Alone.											
December	2 300	80	60	1 100	48	29	100	135	16	14	35.7
January	2 200	80	55	1 500	43	27	100	150	7	6	7.4
February	3 300	120	80	1 550	40	16	100	240	3	1	4.8
March	3 100	85	48	3 400	60	20	100	925	19	12	27.8
April	2 000	55	31	1 300	40	10	100	90	7	2	8.0
May	3 500	75	50	620	17	7	100	24	1	0	0.0
June	8 000	165	125	1 200	40	25	100	100	4	3	20.8
July	3 900	180	130	1 500	70	39	100	80	9	4	11.5
August	11 300	240	180	4 900	85	51	100	260	14	6	29.2
Average *	5 700	143	103	1 900	50	26	100	111	7	3	13.9
1908–1909. Period of Combined Coagulation and Disinfection.											
December	8 100	70	35	760	35	7	0.0	90	8	2	0.0
January	7 200	85	40	2 000	60	6	0.0	70	10	2	4.3
February	3 700	90	34	41	27	4	0.0	17	4	0	0.0
March	4 700	70	35	260	14	3	7.2	2	1	0	0.0
April	3 000	60	32	52	8	2	0.0	41	1	0	0.0
May	1 600	65	31	10	5	1	0.0	7	1	0	0.0
June	7 200	200	60	6	3	0	4.5	2	1	0	0.0
July	4 800	220	100	12	5	1	0.0	3	1	0	0.0
August	2 000	90	55	6	5	2	0.0	2	1	0	0.0
Average *	3 700	127	56	17	5	1	1.0	11	1	0	0.0

*April to August inclusive.

During the period when coagulation alone was used, the color of the raw water averaged 0.43 and the color of the filter effluent averaged 0.09, a reduction of 79 per cent. During the period of combined coagulation and disinfection, the color of the raw water averaged 0.38 and of the filter effluent 0.14, a reduction of about 62 per cent. The removal of organic matter was 56 per cent.,

judging from albuminoid ammonia, and 52 per cent., judging from oxygen consumed during the period of coagulation alone, and 42 per cent. of the albuminoid ammonia and 41 per cent. of the oxygen consumed were removed during the period of combined disinfection and coagulation. During both periods, the filtered water was free from turbidity and sediment. While the albuminoid ammonia and oxygen consumed results were higher during the

TABLE IV.

RELATIVE REMOVAL OF BACTERIA, COLOR, AND ORGANIC MATTER BY MECHANICAL FILTRATION WITH AND WITHOUT DISINFECTION.

	Per Cent. of Bacteria Removed.						Per Cent. Reduction of		
	In Coagulation Basin.			By Entire System.					
	At Room Temp.	At Body Temperature. Total.	At Body Temperature. Red.	At Room Temp.	At Body Temperature. Total.	At Body Temperature. Red.	Color.	Albuminoid Ammonia.	Oxygen Consumed.
1907–1908. Period of Coagulation Alone.									
December	52.2	40.0	51.7	94.1	80.0	76.7	47.5	40.0	47.0
January	31.8	46.2	50.9	93.2	91.2	89.1	62.2	19.9	6.5
February	53.0	66.7	80.0	92.7	97.5	98.7	82.4	57.9	54.2
March	0.0	29.4	48.3	70.2	77.6	75.0	62.8	28.5	0.0
April	35.0	27.2	67.8	95.5	87.3	93.5	80.0	52.5	49.0
May	82.3	77.3	86.0	99.3	98.7	100.0	89.7	69.1	67.9
June	85.0	75.8	80.0	98.8	97.6	97.6	79.2	54.4	60.4
July	61.5	61.2	70.0	98.0	95.0	96.9	73.9	45.7	21.4
August	56.7	64.6	71.7	97.7	94.2	96.7	70.8	60.3	60.0
Average*	64.1	61.2	75.1	97.9	94.6	96.9	78.7	56.4	51.7
1908–1909. Period of Combined Coagulation and Disinfection.									
December	90.6	50.0	80.0	98.9	88.6	94.3	45.5	20.7	5.3
January	72.2	29.4	85.0	99.0	88.2	95.0	41.7	32.7	10.0
February	98.9	70.0	88.3	99.5	95.6	100.0	68.8	61.8	64.3
March	94.5	80.0	91.4	99.6	98.6	100.0	81.6	74.0	71.7
April	98.3	86.7	93.7	98.6	98.3	100.0	56.7	24.7	18.3
May	99.4	92.3	96.8	99.6	98.5	100.0	54.1	62.4	64.0
June	99.2	98.5	100.0	99.9	99.5	100.0	76.2	36.4	45.3
July	99.7	97.7	99.0	99.9	99.5	100.0	51.3	21.5	21.7
August	99.7	94.4	96.4	99.9	98.9	100.0	73.6	62.6	53.8
Average*	99.3	93.9	96.8	99.6	98.9	100.0	62.4	41.5	40.6

* April to August inclusive.

TABLE V.

RELATIVE COST OF CHEMICALS FOR MECHANICAL FILTRATION WITH AND WITHOUT DISINFECTION.

	Chemicals Used, Grains per Gallon.						Cost per Million Gallons Filtered.						
	1907–1908.		1908–1909.				1907–1908.			1908–1909.			
	Sulphate Alumina.	Soda Ash.	Sulphate Alumina.	Soda Ash.	Bleach.	Chlorine (x).	Sulphate Alumina.	Soda Ash.	Total.	Sulphate Alumina.	Soda Ash.	Bleach.	Total.
December	0.85	0.38	.91	—	.102	.065	$1.22	$0.54	$1.76	$1.30	—	$0.18	$1.48
January	1.06	.57	.92	—	.102	.065	1.52	.82	2.34	1.32	—	.18	1.50
February	1.37	.91	.89	—	.111	.071	1.96	1.30	3.26	1.27	—	.20	1.47
March	1.63	.95	.85	0.24*	.221	.141	2.33	1.36	3.69	1.22	$0.34*	.40	1.96
April	1.92	1.39	.83	.64	.183	.117	2.75	1.99	4.74	1.19	.93	.33	2.45
May	1.86	1.52	.91	.70	.144	.092	2.66	2.17	4.83	1.30	1.00	.26	2.56
June	1.84	1.55	.88	.68	.175	.112	2.63	2.22	4.85	1.26	.97	.31	2.54
July	1.77	1.51	.85	.66	.180	.115	2.53	2.16	4.69	1.22	.95	.32	2.49
August	1.88	1.60	.93	.69	.180	.115	2.59	2.29	4.88	1.33	.99	.32	2.64
Average†	1.85	1.51	.88	.67	.172	.110	2.63	2.17	4.80	1.26	.97	.31	2.54

(x) Available chlorine parts per 100 000.
* No soda used until March 15.
† Average, April to August inclusive.

TABLE VI.

Results of Disinfection of Effluent from Pre-Filter.

1909.	Bleach, Grains per Gallon.	Chlorine, Parts per 100 000.	Cost per Million Gallons.	Bacteria per c.c.							Per Cent. of Bacteria Removed.		
				Before Disinfection.			After Disinfection.						
				At Room Temp.	At Body Temp.		At Room Temp.	At Body Temp.		Per Cent. of 1 c.c. Samples Contain. B. coli.	At Room Temp.	At Body Temperature.	
					Total.	Red.		Total.	Red.			Total.	Red.
February	.025	0.016	$0.04	2 300	53	25	200	26	6	16.7	91.3	51.0	76.0
March	.055	0.035	.10	1 300	35	20	185	19	6	21.7	85.8	45.7	70.0
April	.047	0.030	.08	900	24	13	220	11	5	14.3	75.6	54.2	61.6
May	.047	0.030	.08	155	20	10	22	7	2	10.0	85.8	65.0	80.0
June	.049	0.031	.09	1 260	90	44	110	6	2	14.3	91.3	93.3	95.5
July	.072	0.046	.13	1 200	155	110	12	6	1	9.5	99.0	96.1	99.1
August	.053	0.034	.10	520	101	84	21	8	3	10.0	96.0	92.1	96.4
Average*	.054	0.034	.10	890	71	47	95	9	3	18.3	88.9	74.4	83.8

* March to August inclusive.

TABLE VII.

CHEMICAL ANALYSIS OF MERRIMAC RIVER WATER AND EFFLUENTS FROM MECHANICAL AND PRE-FILTERS.

	Appearance.		Ammonia.			Nitrogen as			
	Turbidity.	Color.	Free.	Albuminoid.	Chlorine.	Nitrates.	Nitrites.	Oxygen Consumed.	Alkalinity.
Merrimac River Water.									
1908	0.6	.43	.0105	.0195	.368	.010	.0005	.49	1.0
1909	1.0	.38	.0147	.0201	.425	.011	.0010	.55	1.0
Effluent Mechanical Filter.									
1908 (*a*)	0.0	.09	.0138	.0085	.408	.013	.0004	.23	1.4
1909 (*b*)	0.0	.14	.0144	.0113	.653	.012	.0001	.33	1.0
Effluent Pre-Filter.									
1909	0.1	.37	.0097	.0170	.438	.020	.0004	.50	1.0

(*a*) Coagulation alone used.
(*b*) Combined coagulation and disinfection used.

latter period, when sulphate of alumina was being used in combination with bleach, than during the earlier period when larger amounts of coagulant were being used alone, these results are no higher than those found in many municipal water supplies considered to be of good quality. The amount of color in the filtered water during the latter period of operation averaged 0.14, Hazen's scale, and was probably as high as could be allowed in practice without being noticed by consumers. Better removals of color and organic matter could have been obtained by increasing the coagulant during the latter period, but this would have increased the cost and have defeated the object of the experiment. During neither period was any trace of sulphate of alumina detected in the filtered water, and during the period when bleach was added to the raw water, hypochlorites were never found in the effluent from the filter. No taste or odor was noticed in any of the samples when

they were examined in their natural state, but when heated, the characteristic odor of bleaching powder could be occasionally detected by the trained observer, although this odor was so faint that it would probably pass unnoticed unless it were carefully sought for.

From a bacteriological viewpoint, the results of combined coagulation and disinfection were far better than those obtained by coagulation alone, the average removal of bacteria by the combined process being 99.6 per cent., as compared with a removal of 97.9 per cent. during the corresponding period when no disinfectant was used. The effect of disinfection was most noticeable in the character of the water as it flowed to the filter from the coagulation and sedimentation basin. Here a removal of 99.3 per cent. of the bacteria was effected during the disinfection period, as compared with a removal of 64.1 per cent. during the period when coagulants alone were used. During the period of simple coagulation, the average number of bacteria in the water applied to the filter after treatment was 1 900 per cubic centimeter, and in the filter effluent was 111 per cubic centimeter, while during the period when bleach was used, the numbers of bacteria averaged 17 per cubic centimeter in the basin effluent and 11 per cubic centimeter in the filtered water. Not only was the combined coagulation and disinfection more satisfactory as judged by the removal of bacteria, but it was eminently more satisfactory as judged by the consistently low numbers of bacteria both in the effluent from the coagulation and sedimentation basin and in the effluent from the filter. To state the bacterial results differently, about 30 per cent. of the samples of fi ter effluent contained more than 100 bacteria per cubic centimeter, and B. coli were present in one cubic centimeter in 12 per cent. of the samples during the period when coagulation alone was used, while only about one per cent. of the filtered water samples contained more than 100 bacteria per cubic centimeter and B. coli were not found in one cubic centimeter of the effluent during the time the disinfectant was employed. Furthermore, during the disinfection period, none of the samples of the settling basin effluent contained more than 1 000 bacteria per cubic centimeter, and only about 2 per cent. contained more than 100 bacteria per cubic centimeter, filtration in this case acting

merely as a factor of safety so far as bacterial quality was concerned, the elimination of bacteria being practically effected in the coagulation and sedimentation basin. On the other hand, when coagulation alone was practiced, over 54 per cent. of the samples of the basin effluent contained 1 000 or more bacteria per cubic centimeter, and the burden of producing a bacterially safe water fell upon the filtering medium.

A peculiarity of the disinfection with bleach is that its action upon the types of bacteria determined at body temperature is much less than its effect upon the types of bacteria which are determined by the usual count at room temperature. This effect which has been noted in the bottle experiments previously described has been particularly noticeable in the daily results of the continuous disinfection experiments. With comparatively small amounts of bleach, a practically complete sterilization may appear to be effected when results of the room temperature counts alone are used, whereas counts of the bacteria growing at body temperature show that only a very slight reduction in this class of bacteria has been effected. As experiments were continued, the amounts of disinfectant which were non-effective in satisfactorily reducing the body temperature counts were also shown to be occasionally ineffective in reducing the room temperature counts. Under these conditions it is often found to be the case that the numbers of bacteria determined at body temperature were many times greater than the numbers determined at room temperature. This phenomenon is well illustrated in the results of the bottle experiments and was of common occurrence in the continuous disinfection experiments. In the latter portion of the experiments when the amount of disinfectant had been somewhat increased, consistently low numbers of bacteria determined at room temperature were accompanied by satisfactory body temperature counts. In other words, the satisfactory elimination of the types of bacteria growing at body temperature requires a somewhat greater amount of disinfectant than would be judged to be the case from the usual room temperature counts. This selective action appears to be a peculiarity of the disinfectants whose effectiveness depends upon their oxidizing action, and is to be noticed also in the experiments with permanganates. It has never been observed in experiments

with copper treatment or with other metallic or organic disinfectants. As to what particular significance these resistant types may have cannot be definitely stated at this time, but as they are found in considerable numbers in sewage and polluted waters, but are practically absent from the better classes of surface and ground waters, their removal should at least be attempted when disinfection is relied upon to furnish a hygienically safe water.

With sulphate of alumina and soda at one cent per pound, and bleach averaging 37 per cent. available chlorine at one and one-fourth cents per pound, at which prices they can be purchased in large lots, the cost for chemicals averaged about $4.80 per million gallons for plain coagulation and about $2.54 per million gallons for combined disinfection and coagulation. In other words, a saving of nearly half the cost of chemicals was effected by the use of the combined process, and the capacity of the filter was increased somewhat, while the filter effluent was of much better quality bacterially, and only slightly inferior chemically, to that produced by the use of sulphate of alumina and soda without disinfection. The combined process, however, must be watched even more carefully than is usual in ordinary mechanical filter practice, since the amount of bleach to be used varies with the character of the water, and the usual simple physical and chemical tests by which the necessary proportion of sulphate of alumina may be judged are of no avail in showing the bacterial quality of the water. Competent chemical and bacteriological supervision is already practiced at the larger mechanical filter plants and in these the combined process could undoubtedly be used to advantage. For small plants, such as often receive only scant expert supervision under present conditions, part or all of the expense of the necessary services of a man trained in bacteriology and chemistry would be offset by the reduction in cost of treatment, and in addition the hygienic efficiency of such plants would be greatly increased. Under present market conditions, bleach cannot be purchased at the price quoted above except in large lots, and for this reason the saving to small filter plants in the cost of chemicals would be relatively less than in the case of the larger plants.

DISINFECTION OF MERRIMAC RIVER WATER AFTER FILTRATION THROUGH A ROUGHING OR PRE-FILTER.

On February 1, 1909, studies were commenced of the continuous disinfection of Merrimac River water after it had been passed at a rate of 50 000 000 gallons per acre daily through a roughing or pre-filter containing 48 inches of sand of an effective size of 0.45 millimeter. The effluent from this filter flowed into a tank with a capacity of 30 minutes' flow from the filter, and a strong solution of bleaching powder was run into this tank continuously, the end of the solution pipe being located in the center of the inflowing stream of water. The amount of bleach to be used was judged entirely by the results of the bacterial analyses, the attempt being made to obtain an effluent of the same quality as that obtained from the best water filters at the experiment station by the use of the least possible amounts of disinfectant. The addition of the largest amounts of bleach used caused no appreciable change in the chemical quality of the water, the average analysis of which is shown in Table VII.

During February, when bleach equivalent to 0.016 part available chlorine was used, the bacteria were reduced from 2 300 per cubic centimeter to 200 per cubic centimeter, an average removal of about 91 per cent. Many of the samples during this period were of satisfactory quality, but over 60 per cent. of the samples contained more than 100 bacteria per cubic centimeter. During March, April, May, and June, the amount of bleach used averaged about twice as much as that used in February. In this period, the numbers of bacteria before disinfection varied from less than 200 to about 2 300 per cubic centimeter, and the numbers after disinfection between 22 and 220 per cubic centimeter. During March and April, the removal of bacteria averaged 86 per cent. and 76 per cent. respectively, 26 per cent. and 19 per cent. respectively of the samples collected during these two months containing more than 100 bacteria per cubic centimeter, and 4 and 10 per cent. respectively of the samples containing over 1 000 bacteria per cubic centimeter. Throughout May, the effluent was of satisfactory quality, none of the samples containing as many as 100 bacteria per cubic centimeter, but, owing to the low numbers of bacteria in the water before disinfection, the average removal was only 86

per cent. During June, the average removal of bacteria was 91 per cent., owing to an increase in the numbers in the water before treatment, but 14 per cent. of the samples contained more than 100 bacteria per cubic centimeter. During July, the proportion of bleach was slightly increased, averaging 0.046 part available chlorine per 100 000. The result was an average removal of 99 per cent. of the bacteria with none of the samples showing more than 100 bacteria per cubic centimeter. During August, the amount of bleach used was somewhat less than in July, with the result that the average removal of bacteria was only 96 per cent., and 8 per cent. of the samples contained more than 100 bacteria per cubic centimeter.

It may be of interest to mention that the disinfected effluent was pumped to a storage tank from which it was applied to a secondary filter. The numbers of bacteria in this water after storage of four to eight hours were always higher than in the effluent from the disinfection tank, and even after filtration through the secondary filter the numbers of bacteria were higher than immediately after disinfection. This increase in bacteria during storage is quite common, and was observed at times in the effluent from the pre-filter before disinfection was practiced. The ratio of increase, however, after the disinfection experiment was begun was much greater, and this can be attributed to the destruction of the natural bacterial balance in the water which permitted certain types of bacteria to multiply. These types were the more resistant forms which had escaped destruction, but which, so far as we know, have no sanitary significance.

The cost of disinfection during the last six months varied from eight to thirteen cents per million gallons, with bleach containing 37 per cent. available chlorine at one and one-fourth cents per pound. To this should be added the cost of extra equipment for adding the disinfectant, which would be comparatively small, and the cost of bacteriological supervision, without which the process could not be satisfactorily employed. As the experiment was continued, it was evident that while very small amounts of bleach were effective most of the time, much larger amounts must be added at all times if a constantly effective disinfection is to be maintained, as none of the usual chemical tests indicate when the

smaller amounts will fail to be effective. Furthermore, the peculiar resistance of the types of bacteria growing at body temperature mentioned in the previous pages was noted in this experiment, and if a safe drinking water is to be produced from the Merrimac River water by this process, considerably larger amounts of disinfectant will have to be used than the results of the usual counts of bacteria at room temperature would indicate. The results of this experiment are shown in Tables VI and VII.

CONCLUSIONS.

A complete sterilization of a highly polluted water of the character of the Merrimac River cannot be obtained by the use of either permanganate of potash or bleaching powder, except by the use of extremely large amounts. By the use of permanganate in the proportion of 0.5 part per 100 000, or of bleach in the proportion of 0.1 part per 100 000, a reduction in total bacteria amounting to about 99 per cent. may be obtained.

When bleach is used in combination with sulphate of alumina in mechanical filtration, a satisfactory bacterial removal may be obtained at much less expense for chemicals than when sulphate of alumina is used alone. In such a process, the disinfection occurs in the coagulation basin before the water reaches the filter, and subsequent filtration introduces a factor of safety which greatly adds to the effective purification of the water and greatly reduces the chances of the occasional failure of the process. In the experiments quoted, an effluent of better quality bacterially was obtained by the use of about 0.9 grain sulphate of alumina and about 0.7 grain of soda per gallon in combination with bleaching powder equivalent to 0.11 part per 100 000 available chlorine than when nearly double the amounts of sulphate of alumina and soda were used without the disinfectant.

The experiments upon the continuous disinfection of Merrimac River water after its passage through a high rate roughing or prefilter indicate that in order to obtain an effluent containing low numbers of bacteria at all times, the use of bleach equivalent to .05 to 0.1 part per 100 000 available chlorine will be necessary. By preliminary filtration before disinfection, the amount of disinfectant required is much less than would be required for treatment

of the raw water, but it is probable that an effluent of more uniformly safe quality would be produced if the disinfection process had preceded the filtration, as was the case with the mechanical filter. That the small amounts of bleach used were entirely eliminated is evident by the growths of bacteria which occurred in the disinfected water when it was held in a storage reservoir.

No form of disinfection should be practiced without competent bacteriological supervision. While the disinfection process might be worked efficiently at times, only by frequent and complete bacterial analyses can a constantly efficient disinfection be maintained. The peculiar resistance of some of the types of bacteria growing at body temperature to the disinfection action of bleaching powder and similar oxidizing agents, and the possibility that these types may have some sanitary significance, would suggest that tests for these organisms be made a part of the routine bacterial examinations and that sufficient amounts of disinfectant be employed to constantly eliminate these types in order that the treated water may compare with natural waters of the same degree of purity. The use of disinfection would tend to introduce a feeling of false security, which in case of the failure of the process at any time might result in serious consequences to the health of the consumers. For this reason alone, if for no other, the disinfection should be followed by filtration, which would tend to reduce the chances of failure.

DISCUSSION.

MR. ROBERT J. HARDING.* I would like to ask Mr. Gage a question in regard to the 37 or 40 degree counts. In a raw water with 5 000 bacteria from the 20 degree count, about how many bacteria did you get in the 37 degree count?

MR. GAGE. The numbers varied. Here are some figures from the tables. In the raw water in one experiment: At room temperature, 3 400 colonies; at body temperature, 30; red colonies, 12. In another experiment in the raw water, 1 400 at room temperature, 75 at body temperature, and 14 red colonies. In the same experiment, with bleach equivalent to 5 parts per million available

* Superintendent and Engineer Board of Public Works, Poughkeepsie, N. Y.

chlorine, the count was 15 at room temperature, 35 at body temperature, with no red colonies. With 15 parts per million in the same experiment, we found 1 colony at room temperature, 26 at body temperature, and no red colonies. That is a constant feature all the way through. We thought when we first found them that these high body temperature counts were abnormal and we began to throw them out, but as the experiment progressed, we found they occurred constantly through all the bleach and permanganate treatments. We did not find this phenomenon with any other disinfectants, except these oxidizing agents.

MR. LEONARD METCALF.* I would like to ask Mr. Gage whether he observed in any of these experiments that any taste was imparted or was left in the water after treatment with these disinfectants in the different quantities, such as was referred to by Dr. Otis in his paper this morning.

MR. GAGE. I was rather expecting this question of Mr. Metcalf's after the discussion this morning. We have occasionally used the effluent from this mechanical filter for drinking purposes in the laboratory, and no perceptible taste or odor was noticed. That was in the water after it had been on ice. When the odor was taken after heating, in a few cases a faint odor of bleach would be detected. After the meeting this morning, I was talking with some men who had been using the bleach treatment about that very point, and it was stated that this odor is noticeable in case certain kinds of bleach are used, particularly the European bleaches, but is much less apparent, or not noticeable at all, in the case of some of the American bleaches; in other words, it seems to be a factor of the bleach, that is, of the chemical itself, rather than of the purification plant.

MR. ALEXANDER POTTER.† May I ask if in any of your experimental work you have found a higher bacterial count after the water passed through the filters than before, and if so, what you ascribed as the cause?

MR. GAGE. We have never found in the effluent from the mechanical filter a higher count than we found in the applied water. The rate of filtration, 100 000 000 gallons per acre, is so high that

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

† Consulting Engineer, New York.

there is little opportunity in the filter for an increase in the numbers of bacteria. In the other case, the sterilization was done after the filtration. The effluent from the pre-filter after disinfection was pumped into a storage tank and applied to a secondary filter. The increase in the numbers of bacteria in this stored water, that is, the relative increase, has been very much greater since we have been using the disinfectant than it was before we began the disinfection. That is, we may obtain a practically sterile effluent from the disinfection basin, but after the water goes through this storage chamber, where it receives anywhere from two to eight hours' storage before being applied to the secondary filter, the numbers of bacteria may run up to 200 or 300 or even higher. As to what we would ascribe this, it is simply a question of the survival of the fittest and a re-growth of the more hardy types of bacteria.

MR. POTTER. Those hardy types you consider entirely harmless?

MR. GAGE. Entirely harmless.

MR. MORRIS KNOWLES.* I have been much interested in this paper, especially in the conclusions, for it opens a very interesting field for investigation and consideration, as it apparently offers a cheap and a quick method of purifying water; at the same time, however, it is important for us to consider some of the dangers involved in its use. As the author has well said, sand filtration, as a safety adjunct, should not be forgotten or disregarded. Because of the rapidity by which this method of sterilizing water can be made effective, and because of its low cost, we are likely to grow careless, and the fact that we cannot tell of the results of ordinary counts of total bacteria for forty-eight hours and for the counts of sewage bacteria for some time longer should make us cautious about trusting too much to such a method alone.

If the water is comparatively clear, and I take it that these experiments have been made largely upon this type of water, we may be falsely led to think that it is all right, but with the type of water usually purified by mechanical filtration, the clarification itself teaches us, in some measure, when the process is completely carried out, so that the danger of false security, in the latter case, is not so great. But with the use of sterilization for clear water,

* Chief Engineer, Bureau of Filtration, Pittsburg, Penn.

there is nothing to show the eye whether the water is good or not after this treatment; thus, while the process is effective if carefully performed, and while it may permit of greater rates of filtration, still the safety of having a filtration process should not be forgotten and, in the present state of the art, should not be discarded.

There was one remark of the writer which interested me greatly, and that was that the chemical character of the effluent water was not as satisfactory, if both coagulation and sterilization be used, as it was if coagulant alone be used. I think it would be interesting if we could be told why this is so.

MR. GAGE. The reason that the chemical quality of the effluent was not as good was because less coagulant was used. Only as much coagulant was used as was necessary to produce a water of satisfactory appearance. In the first case, with coagulation alone, it was necessary to use nearly double the amount of coagulant in order to remove the bacteria. That is, you can take out the color or a considerable portion of it with a certain amount of coagulant, but to take out the bacteria requires a much larger amount. By using half the amount of sulphate of alumina we were able to get water of fairly satisfactory appearance and chemical quality, — not as good as could be obtained, but one which would pass, and by the aid of disinfection one which was safe bacterially. Have I made it clear?

MR. KNOWLES. Do I understand that bacterially it was better?

MR. GAGE. Bacterially it was better.

MR. KNOWLES. And only chemically it was not so good?

MR. GAGE. Chemically it was not so good. The total removal of organic matter was less simply because we were using less coagulant.

MR. M. N. BAKER.* Mr. President, I should like to ask Mr. Gage whether he has expressed the amount of bleaching powder used in the same terms as those that were used by Dr. Otis in his paper this morning?

MR. GAGE. I think so. They are expressed in terms of the available chlorine.

* President Montclair, N. J., Board of Health, and Editor of *Engineering News*.

Mr. Baker. Dr. Otis did not state as to that; he simply said so much bleaching powder.

Mr. Gage. It is usual in the use of bleaching powder to express it in terms of available chlorine. Bleaching powder varies considerably in strength, depending on where you get it and how long you have kept it.

Mr. Baker. As Dr. Otis is here, perhaps he will clear up that point for us.

Dr. Otis. I think there is no difference in the statement I made and that Mr. Gage makes, except that he uses a larger proportion of chlorine than we use. We use, perhaps, one-half part of available chlorine to a million, while he uses one. Mr. Gage's paper was very interesting indeed, but he mentioned only one or two substances which he has used. I should like to ask if he has used formaldehyde in connection with the permanganates, or if he has used formaldehyde alone, or if there are any other disinfectants he has used besides those he has mentioned?

Mr. Gage. During the whole series of disinfection experiments, of which this water work is only a part, we have tried at one time or another practically all of the cheaper disinfectants and some of the more expensive. Among others, I might mention formaldehyde, hydrogen peroxide, boric acid, benzoic acid, sodium benzoate, phenol, corrosive sublimate, copper salts, and many others. Of course, formaldehyde and many of the others would be entirely unsuitable for water purification. Peroxide of hydrogen might be used if it could be obtained cheap enough. The permanganates are too expensive at the present prices, and they are also much less effective than the bleach.

Dr. Otis. What form of peroxide have you used?

Mr. Gage. We have used only the straight hydrogen peroxide; we have not tried the sodium peroxide.

ODORS AND TASTES IN THE WATER SUPPLY OF HOLYOKE.

BY JAMES L. TIGHE, CITY ENGINEER, HOLYOKE, MASS.

[*Read September 8, 1909.*]

In 1849, with the development of the water power of the Connecticut River at Holyoke, Mass., and the founding of a new city, a public water supply was naturally required. This was provided by the private corporation that developed the water power, and consisted of a small pipe system connected with a reservoir or cistern of 3 000 000-gallon capacity, into which water was pumped from the river.

For over twenty years this supply served the town, and although the population was increasing and mills and industries multiplying, no steps were being taken by the private corporation to improve the supply or increase its efficiency.

In 1871 the service was so poor and inadequate that public sentiment became aroused, the result of which was the appointment of a citizens' committee to investigate and report upon the advisability of a new municipal water supply.

While the committee was thus engaged, one of the most extensive droughts in the history of the Connecticut Valley occurred, causing nearly all the wells and springs, many of which were still in use in the village, to run dry, and consequently made the whole community dependent upon the reservoir supply.

When the drought, however, was at its highest, the pumping machinery broke down and the village was left without a water supply for three weeks, during which period the citizens were obliged to procure water for their households as best they could, and had either to carry it themselves in buckets and barrels from the river or purchase it from peddlers who sold it from door to door and in the streets.

By the time the pumping machinery was repaired and the water supply again in commission, the village, it was said, could

GENERAL PLAN OF WATER SUPPLY OF HOLYOKE, MASS.

be taken for an Oriental one if judged from the cries of water venders that could be heard on all sides.

This condition of affairs caused so much distress and aroused so much public feeling in the community that even the most indifferent and conservative relative to town expenditures, as well as the most radical, became aroused to the need of the hour and stood ready to support any proposition for a new water supply recommended by the committee, regardless of the cost.

After a very careful and thorough investigation of the matter, in which five sources were considered, the two mountain lakes in the southern part of the town were recommended by the committee as the best source for a municipal water supply.

These two natural lakes, known as Ashley Pond and Wright Pond, the one covering an area of 145 acres and having a maximum depth of 40 feet, and the other an area of 40 acres and having a maximum depth of 38 feet, were separated by a highway only and connected by a culvert, with the nearer or Wright Pond at a distance of about three and a half miles from the center of the village. (Plate I.)

It is needless to state that after what had occurred the report of the committee was accepted and that the necessary legislation was obtained and the works built as soon as possible.

In August, 1873, or within exactly two years after the citizens' committee was appointed, the new works were completed and the expected pure water of Wright Pond, where the gatehouse was located, turned into the pipes. This caused great rejoicing in the town judging from the local paper and the long editorial in appreciation of the great achievement, which wound up as follows:

> "Fountains will beautify our gardens, the street sprinkler's face will wreathe with smiles at the proximity of the fluid he loves to scatter; the church organs will be 'blowed' by water, and the whole town will feel happier and healthier for the introduction of water that is not contaminated by sewage or hog-pen drips."

Apparently the water commissioners, also, felt well satisfied with their work, for in their report the following is found:

> "We congratulate the people that this work has been completed at such comparatively reasonable expense and that they

have a supply of the long-needed, long-wished-for pure water. To be instrumental in initiating, executing, and completing an enterprise of such great domestic and sanitary importance is honor and pleasure enough for one lifetime; and those of our fellow-citizens who first enlisted in this work and have since aided and encouraged us in our labors will long be remembered by an appreciative people."

Public appreciation of public duty is, however, often fickle and short lived; at least such was the case here when, in the summer after the above was written, the new supply became brackish, foul, and unfit to drink.

It was then that the beautiful mountain lakes "surrounded with gravelly shores and fed by copious subterranean springs," sparkling and pure as the nectar drunk by the gods on Mt. Olympus, were discussed in the press and otherwise as nothing more than "foul, slimy, corrupting, fever-breeding pools."

This unpalatable condition of the supply, so soon after its introduction, was very annoying to the commission, and, to add to this annoyance, considerable typhoid and other fevers were prevalent in the town the same season, which were attributed to the foul water, provoking considerable controversy in the press between the local physicians, who were anything but unanimous upon the question.

In this controversy one prominent physician, who made some analyses of the water, wrote as follows:

"As to the Ashley Pond, I have taken water from the pond in four different places at either end and at intermediate points. After letting it stand six days in a properly protected and warm place, I examined it under the microscope for organic matter. The microscope used carried 1-12 object glass and an eyepiece that made the magnifying power sufficient to render the 2 500 000-000th part of an inch of surface or the 75 000 000 000 000 000th part of a cubic inch. This is about as small a business as I care to be caught in alone.

"Furthermore, I have applied a chemical test for organic matter, what is called the permanganate test, a test that will detect organic impurities to a wonderful nicety, and I do not find Ashley Pond water in the least impure. I conclude, therefore, that the water is good for a thirsty man and I do not advise it to be dissolved in whiskey."

To these statements another physician, who was on the opposite side of the controversy, replied by asking why it was that his brother physician did not follow a more simple method in his analyses, in which a common rake or manure fork could be used with better results. "For," said he, "where any farmer sees or hears bullfrogs and other swamp-bred animals all summer and where he obtains the muck to manure his fields, no microscope is needed."

Although the more prominent physicians in the controversy were unanimous in their opinion that the water was not responsible for the fevers then prevalent, the water commission, nevertheless, in order to remove all doubt from the minds of the public, as well as any further ground for controversy, had these shallow areas adjoining the ponds, which were so much the battle ground of discussion, diked off the following year and the height of the ponds raised 14 inches; these dikes, being built of coarse gravel, allowed the water to filter through them.

These improvements were watched with great interest, as it was expected that, with the shallow areas cut off, there would be no recurrence of the trouble of the previous year.

The result, however, was most disappointing, for the water was not only much worse in quality, but continued bad for a period of more than five consecutive months, or over three months longer than in the previous year.

According to the annual report of the water commissioners, the water was foul from the middle of October, 1875, to the end of March, 1876, it having to some a "fishy" taste, while to others it appeared to have a "cucumber" taste, the flavor of "pond lily roots," etc. To most it tasted like that of a slightly acrid and very disagreeable oil, diffusing itself over the mouth and tongue after drinking the water. The bad quality was more marked under high heads than lower ones, and the quality at any given point seemed to vary considerably from day to day, but the characteristic flavor which appeared at the first had not materially changed except in degree.

After making large expenditures in trying to improve the water by diking off the shallow areas, it is needless to say what humiliation the commissioners suffered on finding their efforts unavailing.

To their credit it must be said that they still persisted by trying every remedy at their command to remove the evil. A thorough flushing of the pipe system was resorted to, which, not proving effective, was followed by a temporary arrangement in the gatehouse by which the surface water only was taken into the pipe system. This also failing to give the desired relief, Wright Pond was drawn down and the Ashley Pond connected directly with the gatehouse, but without any improvement in conditions.

Samples of the water were also collected from both ponds and from faucets in different sections of the city and submitted for analyses, with a view to ascertaining if the water was deleterious to health and, if possible, to discover and suggest a remedy for the trouble. All, however, was to no purpose, except that the analyses, as then interpreted, showed the water had not changed in character since it was first analyzed for the investigating committee, "nor did it suggest any increase in impurities that might affect the public health injuriously."

Besides these efforts made to improve the water, the commission had sought information and counsel from outside and found that Boston, New Haven, and New Britain, Conn., and other places had suffered from bad water the same season, and that in Boston the characteristic fishy taste was present in the water; that in Norwich, Conn., in 1873, according to Professor Stillman's report, the water had a fishy-like odor and flavor; that in Hartford and New Haven the same trouble had been experienced, and in the latter city the trouble in 1864 was described as a fishy odor and taste which returned in 1865 in a more offensive form and again in later years; that the Ridgewood water which supplied Brooklyn was affected with the same peculiarity of taste in 1862; that the supply of Winsted, Conn., took on the same condition in the same year; that Burlington, Vt., which was supplied from Lake Champlain, suffered from poor water in 1870, showing that the germs of the evil, whatever they were, did exist in very large bodies of water; that the Albany reservoirs had two distinct causes affecting them at different periods in past years, the one giving to the water the taste and odor of fish, the other imparting to it a musty odor and taste sometimes detected in dead wood; that the Cochituate water, in October, 1864, showed a marked and peculiar taste re-

sembling, in the opinion of some, that of fish, but, in the opinion of the great majority, that of cucumber or some similar vegetable; that, according to the report submitted to the Croton Aqueduct Commission, in August, 1859, by Professor Torrey, and the reports of experts to other boards, the trouble was caused by the existence of microscopic vegetable growths in the water which are not considered deleterious to health.

In addition to this information collected from outside, the advice of Prof. William Ripley Nickol, of the Institute of Technology, was sought, who was then engaged in investigating the poor condition of the water in one of the Boston reservoirs.

Notwithstanding that Professor Nickol had visited Holyoke and investigated, both chemically and biologically, the water and especially the ponds, this skilled expert had no theory at that time to offer as to the cause, and, therefore, no remedy to suggest for the trouble.

For a few years after this long period of foul water the supply, it seems, was uniformly good and whatever prejudices existed against it on account of foulness were fast disappearing.

In the winter of 1879–80, however, the evil returned in all its intensity. This time, Mr. J. Nelson Tubbs, chief engineer of the Rochester Water Works, was consulted because of his experience with the same or similar troubles which had affected the water supply of Rochester.

In his report Mr. Tubbs, besides stating that scientists had substantially agreed that a considerable number of tastes and odors described as "fishy," "woody," "cucumber," "pigsty," etc., were caused by microscopic algæ, advanced the theory, formed, he said, from his own observations and experience, namely, that these microscopic organisms at a certain period of their growth became detached from stalk root or bottom, rose and for a time remained suspended at and near the surface of the water, when under the influence of currents they were spread rapidly over a considerable surface. That if their coming to the surface was in midsummer in a hot sun, they soon died and, through decomposition, gave off the odor so well known. On the other hand, if their coming to the surface was in cold weather, their disintegration and death did not occur so rapidly, and they were carried into the pipe system, where,

under the great pressure there existing, they were broken up and destroyed, which produced the odor peculiar to them.

This, he said, accounted for the peculiar fact, already noticed in the city, that in the lowest points of the system, where the pressure in the mains were greatest and the circulation best, the water was most seriously affected, while on the higher grounds and, consequently, at points of least pressure, the water had least odor and taste. From this view of the case, he continued, it could be readily seen that the popular notion of thorough flushing of the mains as a sure remedy was utterly erroneous, for, instead of abating the evil, it helped only to spread it through the whole system.

To favorably modify and probably cure the existing condition, Mr. Tubbs recommended that the inlet pipe be extended 400 feet further into the pond where the water was about 30 feet in depth. This, he said, would place the inlet pipe at such a depth below the surface of the water that the current into the pipe would create a commotion or draft at the surface of the pond, and the action of the prevailing winds would float to the shore all matters held in suspension at or near the surface, allowing them to settle there and prevent the water in the central portions of the pond from becoming impregnated with their peculiarities in any way.

After this report was made public, exceptions were taken to it by a local engineer, who claimed that Mr. Tubbs' reasoning was wholly wrong and that he (the local engineer) knew what caused the evil and, what was still better, knew of, as he said, "a simple, tried and sure method of avoiding it."

To be able to tell in those days with certainty the cause of odor and taste in water supplies, when such were so common all over the country, was sufficient to distinguish any scientist, but to be able to prescribe a simple cure for them also was more than sufficient to make that scientist renowned for all time.

Was it any wonder, then, that the City Council, as the direct representatives of the people, welcomed these statements of this engineer and requested him to investigate and report upon the matter as soon as possible. This he did, and his report is so novel and shows so much ingenious theorizing and speculation that it may be of interest enough to give a part of it here, which is as follows:

"My theory is this: That in our ponds, as in most others, a great deal of vegetation exists. When this dies in the autumn, its decay dissolves it in the form of an essence, which is very dilute in the pond, and is not evident to the taste, sight, or smell because of its dilution. It then enters the pipes and, because of a property which I claim to have discovered and which is the key to any and all of the phases of the case that I have ever met with or heard of, that is, simply its greater weight than water, it settles gradually until it fills all hollows in pipes to such degree as the current of water in the same will permit. It will then flow on, impregnating the water in no great degree, nor creating much trouble only in such cases as where the water is drawn from the hollows which are already nearly filled with the same. This process of filling up the pipes with this essence goes on in this milder way until such time as it has reached the lower end of any given pipe or main in which the flow is more or less sluggish. Now a condition is brought about by which the water, which up to this time was only slightly tainted, begins suddenly to be intensely bitter, while in some localities, oftentimes but a few yards or even feet distant, the water will be passably good, while in some others there will be neither taste nor smell evident at any time in the whole season. All of these phases are easily explained as follows: When the essence in its slightly bitter concentration reaches the lower extremity of a main it then becomes concentrated, till, in its most intense concentration, *it begins to fill up from the lower end* much as water would fill up; and any person drawing water in the concentrated essence would, of course, draw the impurity, while another party situated on the same pipe, but above the level to which the impurity had filled up, would draw only the degree of impurity as had time to accumulate in its passage from the pond, which is generally very slight, and depends for its amount on the sluggishness of flow in that particular pipe, or even portion of the same, and also on the distance from the reservoir. Both these elements combine to modify the taste, and both must be reckoned on in accounting for it at any given place.

"The following are a few of the many seeming paradoxes relating to this water question, each and all of which have occurred time and again and which can be explained every time by the extra weight of the impurity, by virtue of which it seeks the lowest points at first and then, by filling back, will evidence itself only at and below the level to which it has attained, with such modifications as quickness of current and other circumstances bring about.

"CASES IN POINT.

"Water may be drawn, both good and bad, out of the same pipe at the same time and at nearly the same place. Impure water

may be drawn at one hour and pure water at another hour out of the same faucet, and this can be often repeated. Cause: a quickness of current would cause it to go away from a given place, and would cause it to appear at a higher level, in some other place than its ordinary accumulation had carried it to. The other state of affairs will again prevail when the current assumes the usual flow. Many other phases of its action can be all explained on this same line of reasoning, only bearing in mind the modifying conditions.

"Good and bad water may also be drawn from the same street main *at the same time*, and at the same level, provided that the *size* of the main varies sufficiently, as if a 12-inch pipe was reduced to a 6-inch, for a distance, and the 6-inch was then connected with a 10-inch, the current which in the 12-inch would be sluggish and admit of accumulation would be four times as rapid in the 6-inch, and would admit of no accumulation, and only the passage in greatest degree of the pure water, which it must be remembered will be forced over the sluggish and heavier deposit in the 12-inch pipe. The water in the 10-inch portion could be a great deal better than that in the 12-inch, as the flow in each is in the ratio of 144 to 100, nearly."

The remedy for the trouble, the report goes on to claim, was the addition of a number of blow-offs and a much more thorough flushing of the pipes, a remedy which, according to the other expert, Mr. Tubbs, would be ineffective and a useless expenditure of time and money.

"When doctors disagree, who shall decide?"

This evidently was what the water commissioners thought at this time, as the recommendations made by Mr. Tubbs were never executed and history does not state whether any attempt was ever made to test the truth of the theories propounded by the local engineer.

From now on foul water for a few weeks in the early spring of nearly every year was taken as a matter of course for which there was no remedy, and was given little attention except in an occasional year when the odors and tastes would be unusually bad.

At these periods, the management was never short of suggestions and remedies from interested citizens. On one occasion the aëration of the ponds by windmills was proposed, and those who advocated the scheme were called windmill theorists. On another occasion, the construction of large ice houses around the shores

of the ponds was suggested, for the purpose of harvesting the ice cut from the ponds, in order to keep open water in the late winter and early spring. But perhaps the most novel suggestion of all was that of placing on the ponds a flotilla of side-wheeler steamboats for agitating and aërating the water.

After the causes of most odors and tastes found in surface water reservoirs became well-known and were traced to specific microscopic organisms, but more especially after the appearance, in 1899, of "The Microscopy of Drinking Water," by Mr. Whipple, the question of odors and tastes was taken up by the Engineering Department with this book as a guide in a somewhat systematic manner by making microscopical examinations of the water at intervals, a work which it has continued to the present time.

On account of the large size of the ponds, the shore lengths of which, including all cut-offs, measuring about ten miles, it was thought advisable to collect samples around the shores at different points as well as from the gatehouse.

For this reason over thirty stations were established from which samples were collected and examined on the field at the same time. This provision of taking samples at different points proved to be a wise one, for not only did it enable the biologist to become acquainted with the plankton of the reservoirs, but when certain specimens were desired, such as volvox, etc., like the successful fisherman, he always knew where to cast his line.

The first spring that the water tasted bad after these examinations were commenced, uroglena was found in Wright and Ashley ponds at all the stations where samples were collected.

Uroglena was also found in the shallow area that was diked off from Ashley in former years, but, strange to say, was not found in that diked off from Wright. The discovery was also made that the small artificial reservoir, known as the Bray Reservoir, located across the road about 250 feet from the Wright Pond, and on the main feeder of the latter, contained no uroglena. (Fig. 2.)

This reservoir was constructed in 1883 and has an area of 22 acres and a capacity of 70 million gallons. When constructed, no stripping was done nor was any of the organic matter removed from the basin except that removed in the grubbing. Its high-water mark is about 20 feet higher than Wright or Ashley, both the latter being on the same level.

It was further discovered that the very small pond of not over an acre in area and but a few feet in depth at its deepest place, located directly across the road from Wright, and having hardly any watershed of its own, but fed by the seepage from the Bray Reservoir, contained uroglena in such large numbers that it was called the incubator.

Although it was always difficult to find the organism itself in samples examined from the tap, yet there was no hesitation in coming to the conclusion that the odors and tastes in the tap water were identical with those in the concentrate of the sample collected in which the organisms were found.

There are no odors or tastes produced by organisms more easily detected than those produced by uroglena. In fact, it is only necessary for the biologist to become acquainted with these characteristics once to never forget them afterwards.

Moreover, the odors and tastes produced by uroglena are always most pronounced in the test tube or counting cell, in which the organisms are concentrated. This can hardly be said of the odors and tastes produced by some of the other organisms, which, although decidedly noticeable in the tap water, may be but faintly if at all noticeable in the concentrate in the test tube or counting cell.

Here it might be well to state that the finding of uroglena at this time in the Ashley system was not unexpected, as these organisms were discovered in the gatehouse some years before by the State Board of Health, who attributed to them the bad quality of the water at that time, and the only surprising thing about them now was the manner of their distribution.

When the above conditions, as stated, were established beyond a doubt, and when it was proved, as far as circumstantial evidence could prove it, that uroglena was and must be the cause of the long-standing trouble in the water, it was suggested that the intake-pipe be extended from a point outside the gatehouse in Wright Pond to Bray Reservoir, in which uroglena had not been found, and that the supply be drawn from Bray and also from Tannery reservoir during the uroglena period.

As both these reservoirs were of small capacity and, therefore, could not be depended upon for any length of time, it was also

suggested that connections be made with the Fomer Reservoir, which was built as an auxiliary supply a few years before, and in which no trouble from uroglena or any other organism had been experienced or were likely to be experienced on account of its small storage and large watershed. This reservoir was located back in the mountains in Southampton on the head waters of the Manhan stream at a distance of about 10 miles from Ashley Pond but discharged into the southerly end of the latter, and, to make connection therewith, required only 7 000 feet of piping. (Plate I.)

These suggestions were favorably considered by the management and the work was executed in the summer of 1903 at a cost of about $25 000.

What the results were going to be were anxiously awaited and perhaps it may be said that disappointment was felt by some at least in the following spring because no uroglena appeared in the ponds, or odors or tastes in the tap water, so that the success of the new remedy could not be demonstrated.

The water was again of good quality in the spring of 1905, and no uroglena was found in the ponds except a few colonies in the middle of April, which disappeared before the month expired.

In the spring, however, of 1906 the old evil returned and the first warning was given in the early part of February when a few colonies of uroglena were found in the intake or Wright Pond. From this time on, the colonies kept increasing until, on the 5th of March, the number of colonies counted was 226 per cubic centimeter.

In a few days after this, the water, which had already an unpleasant fishy taste, became not only unbearable to drink but to cook with, and complaints were thundered into the water department about its condition from all sides. On the afternoon of the 8th of March, in the midst of this tumult of complaint about "rotten water," "dead fish," and so forth, the new remedy was applied by the shutting off of Wright and Ashley and the turning on of Bray and Fomer reservoirs instead. The effect of this change seemed magical, for in seven hours after the change was made not even a trace of the bad tasting water could be detected from a tap in the city. After analyses had shown that the uroglena had disappeared, the system was changed back and satis-

factory water drawn from Wright and Ashley ponds. Hence it was that the new remedy on its first trial proved a success, and fully justified the conclusions that the spring trouble was caused by uroglena in the ponds.

No further trouble with the water was experienced until the autumn of 1907. In the early part of November of that year a couple of colonies of synura were found in a sample taken from the Wright gatehouse, but as the water at this season had not been known to give trouble for a great many years, or, in fact, since the memorable year of 1875, little attention was paid to the matter.

It was only a couple of weeks after, however, when a dozen colonies of synura per cubic centimeter were found in the gatehouse and when the water drawn from the taps began to have an unpleasant taste. A few days later the genuine cucumber flavor made itself perceptible, and toward the end of the month the water tasted apparently as objectionable as it ever did in the worst periods of the uroglena epidemics.

The management, who had already been advised as to the cause of the condition of the water, had the Ashley and Wright ponds put out of commission and the Bray and Fomer supplies substituted, as was done before in 1906 during the uroglena period. The change was made on the evening of December 1, with the result that on the following morning no cucumber or any other taste could be detected in the tap water. Hence again the new remedy proved effective and demonstrated that synura was the cause of the trouble this time.

Like uroglena, synura reveals very plainly its characteristics in the concentrate of the sample, either in the test tube or counting cell, and also like the former these characteristics when once observed are not easily forgotten.

The discovery of synura in Wright and Ashley ponds in the autumn of 1907, giving to the water a cucumber flavor, is more or less suggestive and explanatory of the cause of the conditions that existed in the autumn of 1875 and until the spring of 1876, when the water tasted bad for a period of over five consecutive months.

What occurred then, as it now appears, was an epidemic of synura in the fall followed by an epidemic of uroglena which lasted until the middle of the following March.

This condition would be exactly repeated in 1907–1908 had we the normal uroglena trouble in the winter and spring of 1908. Fortunately, however, uroglena did not follow synura, and the odors and tastes produced by the latter had disappeared in the early part of January.

Before leaving this question of odors and tastes in the Ashley system, it may be of some interest to know that in 1902 the water had odor and taste from the middle of March to the beginning of May; that in 1903 it had odor and taste from the beginning of February to the middle of April; that uroglena was found this year from the beginning of January to the middle of May in Ashley Pond, Wright Pond, in the shallow area diked off from Ashley, and in Bray small pond; that uroglena was not found in Bray Reservoir, in Tannery Reservoir, or in the shallow area diked off from Wright Pond; that the maximum number of colonies of uroglena per cubic centimeter found in Ashley was 37, in Wright 84, in Ashley cut-off 48, and in Bray small pond 662; that in 1904, the tap water was free from taste and odor and the ponds entirely free from uroglena; that in 1905, the water was free from taste and odor and the ponds free from uroglena except in the month of April, when a few colonies were found which disappeared soon afterwards; that in 1906, uroglena appeared in Ashley, Wright, Ashley cut-off, Bray small pond, and Tannery Reservoir between the end of February and the middle of May; that odors and tastes were decidedly noticeable between the beginning of March and the middle of April; that the maximum number of colonies found in Ashley was 32 per cubic centimeter, in Wright 39, in Ashley cut-off 260, in Bray small pond 31, and in Tannery Reservoir, in which uroglena was found for the first time, 51; that in the spring of 1907, the water from the tap was of excellent quality and that no uroglena was found in any of the ponds; that in the autumn of the same year the maximum number of colonies of synura found in Wright gatehouse was 38; that in the spring of 1908, the water was free from odor and taste and the ponds free from uroglena and that in 1909 uroglena was found in Wright Pond between April 18 and May 24, the maximum number found being 14 per cubic centimeter, and that in the month of May the water from the tap for a short time had some odor and taste but not of

sufficient intensity to call it very objectionable or to cause the system to be changed.

It must not be inferred that there are no other organisms in these ponds and reservoirs but uroglena and synura. On the contrary, specimens apparently of nearly all the fresh water plankton are met with but as, so far as has been noticed, they have caused no odor or taste in the water, no attention has been paid to them here.

Aphanizomenon, dinobryon, and asterionella are very common, and the first is abundantly found throughout the autumn, especially in the months of November and December. Unlike many other ponds and reservoirs, one very peculiar but fortunate thing about the Ashley system is that the water in these ponds is always best in the summer season or between the spring and fall overturns, when it contains practically no microscopic organisms, and the troublesome summer organism, anabæna, has not acquired a foothold here as yet, which cannot be said, however, of one of the other storage reservoirs of the city, known as the Whiting Street Reservoir.

In 1884, when it was thought advisable to increase the supply, the Whiting Street Brook, so-called, was added; this flowed on the other side of the city from the Ashley system in Northampton, just across the Holyoke boundary line. (Plate I.) When this brook was taken, its normal flow was considered sufficient as an additional supply for some years, and consequently only a small intake reservoir, having less than 2 million gallons capacity, was constructed.

In 1890, when it was again thought necessary to increase the supply, a large storage reservoir was built on this brook and located about a thousand feet above the intake and at the foot of Mt. Tom. This reservoir covers an area of 114 acres, has a capacity of 500 million gallons, and an average depth of 13 feet. Its elevation at high-water mark is 32 feet higher than the high-water mark of the intake, and the reservoir is so arranged that it can either feed the latter by letting it flow thereto in an open channel, or the city mains directly, through a pipe line laid from its gatehouse. (Fig. 1.)

In the construction of the reservoir, the basin, which was both meadow and woodland, was not stripped, and few, if any, of the stumps were removed.

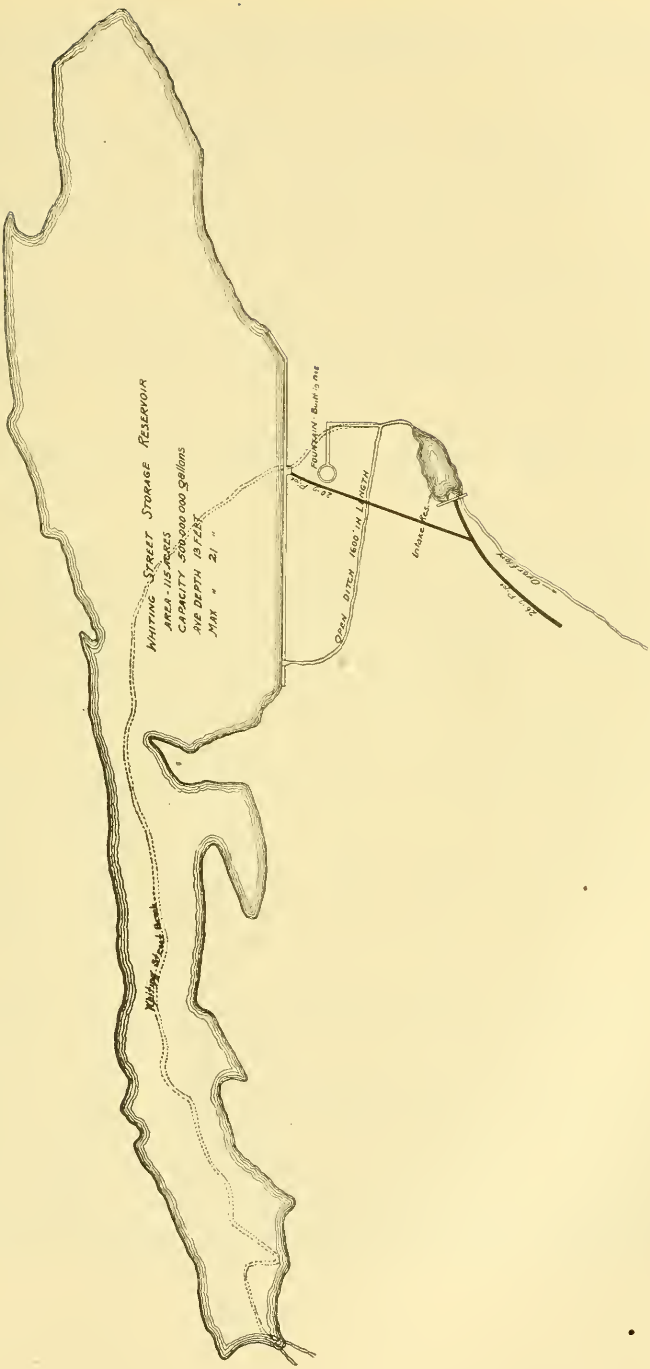


FIG. 1.

THE WHITING STREET RESERVOIR, ADDED IN 1890.

This reservoir from the beginning contained its share of microscopic growths and that of anabæna, especially in the summer time.

Notwithstanding that in occasional years this organism was so abundant that a green scum covered over almost all of the surface of the reservoir and that the turbidity of the water increased to three or four times its normal, no general complaint was heard about its quality from the consumers.

It should be said here that the water was not being served directly from the large reservoir, but first let down the channel to the intake above described before being taken into the pipe system.

In the summer of 1906, more pressure was desired in the territory served by this water, and accordingly it was proposed to draw from the storage reservoir direct and thus increase the pressure about 14 pounds.

At this time the greater part of the surface of the reservoir was covered with the old Paris green mantle, as it was termed, and the water contained anabæna to the number of 25 500 cells per cubic centimer and had a turbidity of about three times the normal.

On the 3d of August the change was made with the result that the next morning the tap water in the territory served was absolutely unfit for use, even for washing purposes.

This condition, of course, caused no end of complaints, some of which, although bitter in the extreme, had their humorous side, as was instanced in one case when a party, who evidently had lived at some previous time in the neighboring city down the river, in describing the vile characteristics of the water, said that it smelled and tasted as bad, or even worse, than the Springfield water.

It is needless to say that the higher pressure had to be sacrificed and the supply changed back and drawn again from the intake reservoir, after which no more complaints were heard.

This dissertation on the Whiting Street Reservoir supply has not been given for the purpose of describing the troubles caused by anabæna in water, which are well-known to water-works officials, but for the purpose of showing the value of aëration as applied to surface-water reservoirs, a feature, apparently, that in the past had never received the recognition it deserved.

No experiments on a large scale could show in a more practical way the value of aëration than this. For here was a water, absolutely vile in taste and odor, improved so much as to make it palatable and unobjectionable to the consumer, because of its being conveyed at the rate of from a million to a million and a half gallons per day in a narrow open ditch about 1 600 feet in length, before being taken into the pipe system.

In order to find out if some further remedy could not be applied to improve still more the quality of this water, the advice of Mr. Allen Hazen, of the firm of Hazen & Whipple, of New York, was sought. Mr. Hazen, in company with Mr. E. E. Lochridge, of Springfield, who had a large experience with anabæna in the Ludlow supply, visited the reservoir. Whatever magic these gentlemen performed, anabæna disappeared within two weeks after and has not appeared again to give any trouble from that time to this.

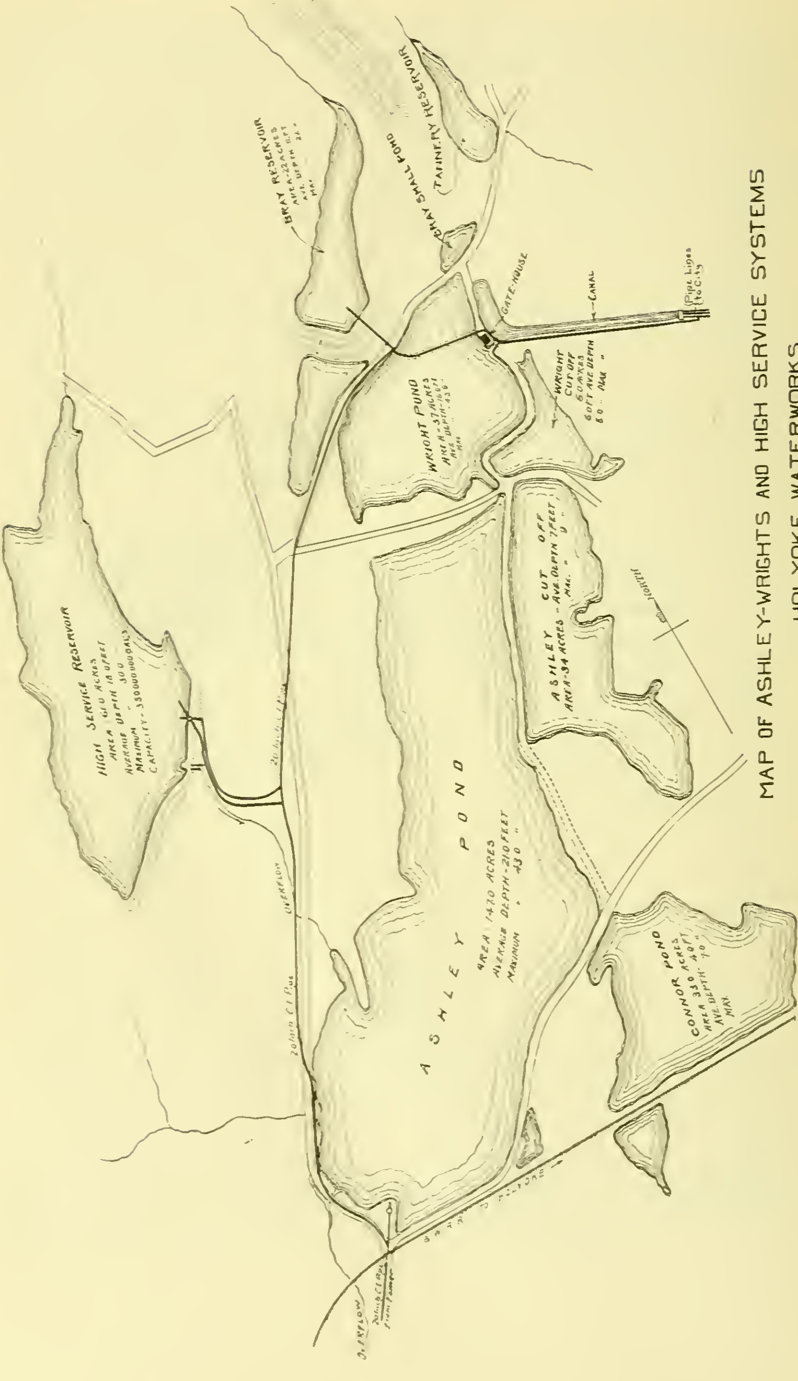
The absence of any trouble from anabæna in Whiting Street, and the good quality of the water drawn from here since then, has been a very fortunate condition, especially last year (1908) when this reservoir had to be substituted for the high-service on account of the poor quality of the water in the latter.

The high-service reservoir is located on what was the main feeder of Ashley Pond, at a distance back in the hills of about 1 500 feet from Ashley, and where the elevation of the brook was 80 feet higher than Ashley.

It covers an area of 61 acres, has a capacity of 350 million gallons, an average depth of 18 feet, and a maximum depth of 30 feet. (Fig. 2.)

Its drainage or catchment area is only 302 acres, but the reservoir can be filled by the Fomer pipe-line, which is extended thereto.

Believing that all reservoir basins, especially distributing reservoir basins, should be as free as possible from organic matter, and having in mind the troubles caused by organisms in the Ashley system of ponds and in the Whiting Street Reservoir, from the basins of which practically none of the organic matter had been removed, and believing also in the theory then prevailing that the removal of all organic matter from reservoir basins was an important factor in the prevention of the growth of troublesome



MAP OF ASHLEY-WRIGHTS AND HIGH SERVICE SYSTEMS
HOLYOKE WATERWORKS

FIG. 2.

organisms, it was determined at the outset that the high-service basin should not only be stripped and cleaned, but that the work should be very thoroughly done.

In accordance, therefore, with this policy, the basin was stripped and cleaned to a very desirable bottom. This necessitated in some places the removal of peaty matter, which covered a considerable portion of the bottom to a depth of from 1 to 3 feet, and in one particular place to a depth of 12 feet, where a pocket of genuine peat was found covering an area of about 2 acres.

But besides the removal of this vegetable matter, considerably more of the material underneath it, which was of a gravelly, clayey character, was removed from a great portion of the basin and placed in the dam or embankment; the latter, containing about 100 000 cubic yards, being built entirely of material taken from within the basin.

In 1899 the construction of the new reservoir was commenced, and, as the cost was practically taken from the yearly income of the water department, it was not finished until the autumn of 1904. In the following winter, the gates were shut to fill the reservoir, which overflowed in the spring of 1906.

Owing to unavoidable delay caused by putting in the new pipe lines, and rearranging the pipe system in the high-service territory, the reservoir was not put into commission, with the exception of a few weeks in the fall of 1907, until the spring of 1908, when, on the 23d of April, the water was turned on for permanent service.

It was not more than a few weeks after this when complaints were received about the bad taste and odor in the tap water, and consequently a microscopical examination was made, which revealed the presence of chlamydomonas.

Samples were now examined on the field, when it was found that the water in the gatehouse contained as high as 1 376 of these organisms per cubic centimeter.

This was on May 26, and on June 1 the number increased to 1 720. The latter was the maximum number found in any of the 146 samples examined between May 26 and the end of August, when at the latter date the organism had practically disappeared.

One important peculiarity noticed about these organisms was that they were not found at or near the surface of the reservoir.

and by taking samples at various points and different depths in the reservoir it was shown that a depth of about 12 feet had to be reached before finding them.

It was also shown that, although these organisms were found at or very near the bottom of the reservoir, they were found most numerous between 12 and 20 feet from the surface.

It is, therefore, evident that these organisms were influenced by temperature or light, as in the gatehouse, which was totally dark and where the temperature was somewhat lower than at the surface of the reservoir, they were found as numerous at the surface of the water as at any point beneath it.

The bad quality of the water from the taps, in the month of May, was very naturally attributed to these organisms, to which was also attributed the dark greenish color of the water, which was very noticeable in the bath tub.

Although taste and odor were very pronounced in the tap water, neither of these characteristics could be detected in the water in the reservoir, which, to the senses at least, appeared to be of good quality.

The taste and odor noticeable in the tap water could not be called either fishy, grassy, or aromatic in character, but were more like those produced by decaying animal matter and seemed to be even more objectionable than the uroglena or synura flavors. Unlike these, however, they were not pronounced in the concentrate or in the counting cell, where the tastes and odors produced by uroglena and synura are always so demonstrative.

When it was seen that the bad condition of the water was likely to last for some time, the Fomer pipe line was turned on, which discharged about a million and a quarter of gallons per day into the reservoir at a point about 100 feet away from the intake pipe. This dilution seemed to serve the purpose, as no complaints about the bad quality of the water were again heard for some weeks.

When they were again heard, however, the trouble, it was thought, was caused by another organism, known as chara,— or probably what the botanist would call nitella, both organisms being practically alike,— which was discovered in the reservoir in the middle of July. Chara is by no means a microscopic organism, like those discussed above, but is a water weed which grows to

considerable size under the surface of the water on the bottom and sides of the pond or reservoir in which it is found. (Figs. 3 and 4.)

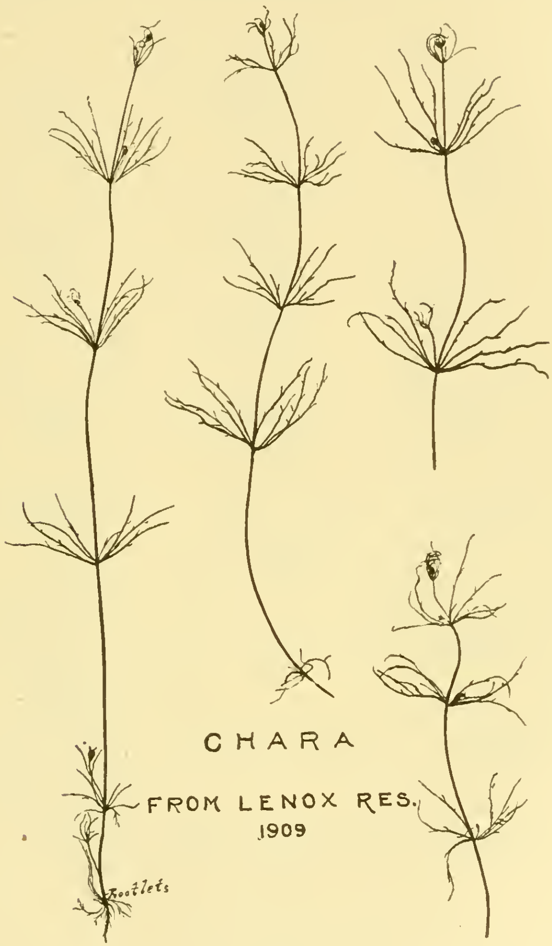


Fig. 3.
Two-thirds full size.

In botany, chara and nitella are classified as genera of the order of characea, which we are told is of great antiquity and without any living relatives now. In many respects the plants of this

order are closely allied to the filamentous algæ, but are distinguished therefrom in their resemblance to the higher plants by having stems, branches, leavelets, etc.

Fig. 4.

Two-thirds full size.

These two genera, which make up the bulk of the characeæ order, are found growing more or less in quiet fresh waters in temperate regions all over the world, and it was in the common species of chara, known as "chara vulgaris," that the important fact of vegetable circulation was first discovered.

The plants of both chara and nitella grow in some places to a length of from 3 to 4 feet, while their stems are not much thicker than a stout needle. Each plant or stem is attached to the bottom by slender thread-like rootlets, and has branches regularly arranged in circlets or whorls, each whorl consisting of an equal number of branches which, according to the species, may be of any number from five to twelve.

The species as found in the high service grew in dense irregular mat-like patches all over the bottom and sides of the reservoir except where the depth of the water exceeded about 20 feet. The largest plants measured about 2 feet in length and had whorls of eight branches spaced from an inch to an inch and a half apart. The areas of the patches, as were found later when the reservoir was emptied, varied from a few square feet to several thousand, the maximum measuring about 50 feet by 120 feet, or 6 000 square feet.

The growth at this place seemed to be the most healthy and luxuriant in the whole reservoir and was exactly at a depth of $13\frac{1}{2}$ feet below the surface of the water. It was at a place, too which one would expect to be the last to find vegetable growths of any kind whatever, because the bottom here was a peninsula running out from the south end of the dam that was excavated to hard pan and rock, not for the purpose of removing vegetable matter, of which there was very little, but for the construction of the dam, for which the material was excellent, it being of a hard, clayey, gravelly character.

But this luxuriant growth in this barren place was not the whole, for as if to show contempt for and independence of anything of a vegetable or organic character, these water weeds grew luxuriantly on the stone pavement of the dam where there was nothing for the rootlets to derive nourishment from except the selected gravel that filled the interstices of the pavement.

Authorities state that the rootlets are for simply holding the plant in place and are not otherwise necessary to its life, since food is absorbed, as in the algæ, directly by the body of the plant from the water in which it lives.

Be this as it may, the writer in trying to raise these plants in glass jars was only successful where an adequate quantity of silt or mud was placed in the jars, as the plants did not thrive but died in the ones where the silt was but scantily placed.

But perhaps one of the most important peculiarities noticeable about this plant was the strong odor therefrom on its being taken out of the water. To many persons who observed this odor it seemed to resemble most nearly that from the skunk. The botanist, it seems, has paid no attention to this property of chara, although he has described the pig-pen characteristic of the plant when decaying. This is the more singular, too, since the odor is decidedly strong in the youngest shoot, in which decay is out of the question.

In the water from the tap, the odor detected would remind one of sulphurated hydrogen, while in the reservoir no odor or taste could be detected in the surface layers of the water or until the lower layers were reached, and then not nearly as strong as from the tap water.

As the summer advanced, the quality of the water gradually became worse, and in the middle of August became so foul that the reservoir had to be shut off entirely and the Whiting Street Reservoir, which is only about 40 feet lower in elevation, substituted to supply the high-service district.

So far as is known, chara is not common in the reservoirs of New England, and up to this time was known only to give trouble in one reservoir in Massachusetts.

This was in the town of Lenox, where a growth of chara, as stated by Mr. I. J. Newton, the superintendent, has been chronic in the reservoir for the past ten or twelve years. In 1898, the taste and odor observed in the supply were attributed to this organism, as have those also which have been observed in the supply from time to time ever since.

After the trouble was traced to this plant, the reservoir was emptied and from 6 to 12 inches in depth of the bottom, which is of a clayey character, was removed. This, however, did not prevent the growth of the organism, as in the following year it appeared again and in a year later grew as luxuriantly as it ever grew before the reservoir was cleaned.

When odor and taste are observed in the water, the remedy is to draw the supply from or near the surface of the reservoir, and the inlet had been arranged so that this could be done at any time. A peculiar remedy, though, to get rid of the chara, was the stocking

of the reservoir with carp, which, the superintendent states, feed upon the young plants and thus destroy their growth.

How much of a delicacy or nutrition these fish can find in such plants can be judged from the analysis made by Mr. Whipple, in the Hazen and Whipple laboratory, of the plants found in the high-service reservoir, which contained, besides water and a little organic matter, 0.22 per cent. of phosphates, 0.36 per cent. of alumina, 0.56 per cent. of sodium, 0.95 per cent. of iron, 2 per cent. of magnesium, 2.64 per cent. of potassium, 2.77 per cent. of manganese, 2.99 per cent. of silica, and 23½ per cent. of lime.

As is seen, the chief mineral constituent of these plants is lime, hence, is it not strange to have such a luxuriant growth in a water comparatively free from lime, if the hardness of the water is any indication of this mineral?—the hardness being only slightly over 2 parts per 100 000 (Clark's scale).

As the high service was unfit for use, it was drawn off in the fall and kept empty during the winter months in order to see what effect this, together with the frost, would have upon the chara growths afterwards.

Moreover, because no odor or taste had been detected in the upper strata of the reservoir, and because the feed or inlet pipe to the gatehouse was at a depth of 18 feet below high-water mark, it was thought advisable, in case there should be any recurrences of the trouble, to be able to draw the supply from or near the surface of the reservoir. To accomplish this a brick well with a stop plank opening was constructed around the end of the inlet pipe to serve this purpose.

Drawing off in the fall and refilling the reservoir in the spring has proved to be a wise procedure, because the quality of the water from the time the reservoir was put in commission again, which was in the middle of June last, to the present time, has been excellent.

The organism chlamydomonas, which was present in such large numbers in the reservoir last year, was not found at all this year, and while the emptying of the reservoir, or frost, or both together, did not kill or annihilate entirely the chara, its growth was affected and retarded so much that only traces of the organism have been found in the reservoir so far this year.

These traces, however, indicate that there is likely to be a considerable growth of this species of water-weed next year. If such does occur, it will be subjected to a much more exacting analysis, especially relative to its adaptability for imparting odors and tastes to water, than it was subjected to last year.

Notwithstanding that the troubles in the Lenox Reservoir are attributed to chara growths, and that these growths had also been known to cause trouble in a reservoir in 1895 in central New York,* yet, because of the peculiarity of the case here occasioned by the large number of chlamydomonas present in the reservoir, and to which the bad quality of the water was attributed previous to the discovery of the chara, the question might be raised as to whether chlamydomonas was not responsible in some unknown manner for the trouble attributed to the chara. It might, therefore, be advisable to await further investigation and evidence before establishing as an absolute certainty that the species of water-weeds as found in the high-service reservoir of Holyoke impart odor and taste to water.

DISCUSSION.

Prof. William B. Mason.† I have the highest appreciation of Mr. Hazen's professional ability, but I could not help being struck by the fact, as stated by Mr. Tighe, that his mere presence in Holyoke cured the evil from which they were suffering. I should like to inquire if Mr. Tighe knows what happened in the still watches of the night, and if he is sure that Mr. Hazen did not put a little copper sulphate into the reservoir. I do not know to what extent the use of copper sulphate is permissible in Holyoke, but we all know that copper sulphate is a mighty agent for ridding waters of material of the sort spoken of, and I was wondering whether it was put in on the quiet or not. (Laughter.)

Mr. Tighe. I will say in answer to Professor Mason that I do not think it was, because Mr. Hazen and Mr. Lochridge were not at the reservoir more than an hour in the forenoon, although they might have come afterwards, unknown to me, in the middle of the night. (Laughter.)

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* See Journal of the New England Water Works Association, Vol. X, p. 252.

† Rensselaer Polytechnic Institute, Troy, N. Y.

Mr. Edward Bartow.* Have any experiments with chemicals been tried in Holyoke, Mr. Tighe? You have several reservoirs there, so that you can take water from one or another as you please, but in many places there is only one reservoir, and chemical treatment or something of that sort seems necessary.

Mr. Tighe. The State Board of Health does not advise the use of copper sulphate, and in our case, on account of the arrangement of our reservoirs, we can get along without its use. When one reservoir is bad all we have to do is to cut it out and draw from another; even in case we cut out our high-service reservoir, the Whiting Street Reservoir is only 40 feet lower, so that by drawing from the latter the loss in pressure is hardly noticed by the consumer.

Mr. W. C. Hawley.† Do I understand that the Massachusetts State Board will not allow even a trial of copper sulphate?

Mr. Tighe. The Massachusetts State Board of Health does not recommend it, at least, and I do not know of any place in Massachusetts where it has been used except some time ago in an abandoned reservoir of the Springfield Water Works for experimental purposes.

Mr. Hawley. I am glad I am from Pennsylvania. Our State Board of Health suggests the use of copper sulphate, approves it, and excellent results have been obtained from its use.

Mr. Leonard Metcalf.‡ I should like to ask whether Mr. Tighe has made any experiments with the use of copper sulphate, or whether the State Board made such an experiment, and if so, with what result?

Mr. Tighe. As I understand it, the State Board made experiments with copper sulphate in connection with the Springfield Ludlow supply, but I could not say with what results. I think the experiments were on anabæna. I am not aware that the State Board experimented with chara in any place in the state, because our reservoir is, so far as I know, the second reservoir in which it has been found in Massachusetts. I do not know of any place in the state where copper sulphate has been used in a

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* Director State Water Survey, Urbana, Ill.

† Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

‡ Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

reservoir from which the water was being used by a city or town, and at Holyoke we have not made any experiments on the chara with copper sulphate.

Mr. Metcalf. I should like to ask Mr. Tighe what the cost of stripping the basin for the reservoir was.

Mr. Tighe. I should think, for the stripping alone, between $60 000 and $75 000.

Mr. George C. Whipple* (*by letter*). The writer has read Mr. Tighe's paper with great interest. It is not often that a busy city engineer takes the time to patiently study out the microscopic organisms found in the water supply under his charge, in the way that Mr. Tighe has done. The city of Holyoke has certainly benefited by the knowledge he has thus acquired, and the citizens have received a cleaner and better water than they otherwise would have.

The historical portion of Mr. Tighe's paper is of special interest, as it serves to emphasize the great step in advance that has been made since the early days referred to, when the bad tastes and odors in the water supply were attributed to almost every cause but the right one. Although we may congratulate ourselves that we understand the subject better than we once did, it is humiliating to think that we still know so little in regard to the conditions which cause the growth of the troublesome microscopic organisms. Although we know many of the factors that influence their development, we are still very much in ignorance as to the particular combination of causes that suddenly brings about a development of anabæna or some other organism in a reservoir that has previously been without them.

During the last ten years the algæ problem has been approached from two different standpoints: First, from that of preventing their growth, and, second, from that of getting rid of their effects. In small reservoirs it has been found possible, by the exclusion of light, to prevent the development of algæ. In large reservoirs, where the exclusion of light is impracticable, the attempt has been made to cut off their food supply by removing the soil from the bottoms of reservoirs. This has been only partially successful and engineers are more and more coming to doubt the expediency of

* Of Hazen & Whipple, Consulting Engineers, New York.

this course, except, perhaps, in certain special cases. Mr. Tighe appears to have had his own troubles in attempting to apply this remedy.

Better success has resulted from the attempts to kill the algæ and get rid of them and their effects, the former by the use of copper sulphate, the later by the use of aëration and filtration. So much has been said about the use of copper sulphate that this topic needs no further discussion at this time. That the method has been successful in many cases must be admitted, but that it has not proved a universal remedy is equally true, and the attempt to use it indiscriminately has sometimes resulted in making bad matters worse. Copper sulphate is like a powerful drug, only to be used on prescription by a competent physician. The attempt to use it as a patent medicine, as has been done in many cases, has had the usual effect of the use of patent medicines. An illustration of this may not be out of place. A water supply with which the writer is familiar suddenly acquired a bad taste and odor which was thought to be caused by algæ growing in the reservoir. Copper sulphate was applied in small doses without benefit. A larger dose was then used, with the result that the odor was much intensified and the water was almost undrinkable. Investigation showed that the pipes and the pressure filter through which the water passed were very heavily loaded with " pipe moss." The use of copper sulphate in the reservoir killed the algæ there and thus suddenly cut off the food supply of the pipe dwellers. Consequently they died and decayed, with the result that the water consumers speedily took to other beverages. This case also illustrates the fact that not all bad tastes and odors in drinking waters are due to algæ and protozoa. Some of the larger and more highly organized forms of life are at times involved. Mr. Tighe's experience with the growth of chara in his Holyoke reservoir is particularly interesting in this connection.

But it is along the line of aëration and filtration that the greatest promise lies. When a water like that of Ludlow Reservoir at Springfield can be made palatable by the simple devices there used, there ought to be hope for many water supplies in New England that now are in disrepute during the hot weather. The conditions are not always as favorable for the economical applica-

tion of aëration and intermittent filtration as they were at the Ludlow Reservoir, but the principles hold good elsewhere and the future is destined to see the construction of many filters and aërators for improving the physical character of the water. Filtration has the additional merit of rendering the water not only clean, but safe from a sanitary standpoint. More and more, people are coming to demand water that is clear and sweet. The consumers of the future are not going to be content with water supplies that possess the negative virtue of being merely not dangerous,— they will demand the positive virtue of cleanliness.

CIVIL SERVICE IN ITS APPLICATION TO THE WATER DEPARTMENT.

BY THE HON. JOSEPH C. PELLETIER, MASSACHUSETTS STATE CIVIL SERVICE COMMISSION.

DISCUSSION.

Mr. John F. Trautwine, Jr.* (*by letter*). Hon. Joseph C. Pelletier quotes the objection:

" The civil service is a farce. Do you suppose that I, in my private business, would be held down to appoint men that somebody else recommended, and be compelled to appoint those men? Can you point out any big business man, any man of affairs, who takes the judgment of some outsider as to the men whom he is to employ in his mill or in his office? "

To my very great surprise, Mr. Pelletier gives, as the answer which he makes to a question of that kind:

" We certainly would not apply such a system to a man's private business; we would not dream of doing it, and it would probably not work well if it were done."

I should have expected Mr. Pelletier to reply more nearly in this fashion:

" What is the alternative? To permit a self-constituted organization of employees and their outside confederates to control the admission to and the dismissals from my service. This is the alternative to which communities without civil service have to submit. Would any big business man, any man of affairs, submit to such conditions? "

Every big and little business man uses the equivalent of civil service examination in the selection of his employees. He does this when he asks his employee what his age, experience, and references are, instead of asking with which clique of the employees he is in sympathy.

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* Civil Engineer, Philadelphia.

Even in our very small establishment we have sets of examination questions prepared for candidates for employment, including even the messenger boy, who is asked, among other things, what street cars he would take in order to reach given locations. The results have been far more satisfactory than those where we have been guided by the recommendations of friends.

If we were a concern of some size (even though not comparing in this respect with a municipality) we should have to intrust the conduct of these examinations to our assistants, and might even find it to our advantage to call in "the judgment of some outsider," as an expert to assist in the choice.

Civil service is merely the common-sense method of all business men extended to meet the requirements of a public body.

Having served upon both sides of the civil service fence (both as examiner and as candidate) I am profoundly impressed with its weaknesses, and I greatly deplore the necessity for its use; but, so long as we tolerate an "economic" system which leads everyone to look out for himself at the expense of the commonwealth, the civil service system will be indispensable.

Hon. J. C. Pelletier (*by letter*). I feel that Mr. Trautwine did not catch my idea exactly, or possibly I did not make myself clear. He urges that in private business many are following the civil service system. They are in-so-far as they are promoting and hiring on the merit system of ascertained fitness. The point I intended to make was that it was objectionable for appointing officers to be obliged to take persons whose fitness had been ascertained by some one else, but that while this was necessary in public affairs, owing to political conditions, in private business no man would submit to it. I judge from Mr. Trautwine's letter that no one else ascertains the fitness of the people whom he employs, but that he reserves this right to himself. I think he would agree with me that if some one other than the person hiring were to choose his employees, and under these conditions he was obliged to hire them or be without help, the system would be most obnoxious. In public life, however, this system becomes necessary, owing to prevailing conditions.

PROCEEDINGS.

Nahant, Mass., June 16, 1909.

The June meeting of the New England Water Works Association was held at Nahant, Mass., on June 16, 1909. The following members and guests were present.

Members.

S. A. Agnew, J. M. Anderson, F. A. Barbour, G. W. Batchelder, J. F. Bigelow, James Burnie, T. J. Carmody, J. H. Child, C. E. Childs, M. F. Collins, G. K. Crandall, J. W. Crawford, G. E. Crowell, E. R. Dyer, E. D. Eldredge, F. F Forbes, F. L. Fuller, F. J. Gifford, J. C. Gilbert, T. C. Gleason, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, J. O. Hall, D. A. Heffernan, M. F. Hicks, Willard Kent, F. C. Kimball, G. A. King, J. J. Kirkpatrick, A. R. McCallum, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, F. L. Northrop, H. E. Royce, A. L. Sawyer, E. M. Shedd, J. E. Sheldon, C. W. Sherman, H. O. Smith, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, W. M. Stone, H. L. Thomas, R. J. Thomas, W. H. Thomas, L. D. Thorpe, J. A. Tilden, W. P. Whittemore, L. J. Wilber, F. B Wilkins, G. E. Winslow, L. R. Woods. — 60

Associates.

Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by F. W. Mattheis; Chapman Valve Manufacturing Company, by E. F. Hughes; Kennedy Valve Manufacturing Company, by M. J. Brosnan; Ludlow Valve Manufacturing Company, by A. R. Taylor; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; Waldo Bros., by H. E. Browne; R. D. Wood & Co., by Wm. F. Woodburn. — 15.

Guests.

W. H. Greenleaf and W. M. Gates, Nashua, N. H.; Milton Thome, assistant superintendent, Portland Water District, Portland, Me.; Mr. and Mrs. E. L. Burnap, Norwich, Conn.; Mrs. L. J. Wilber, Brockton, Mass.; Edwin Leavitt,

Somerville, Mass.; Mrs. George A. Stacy, Mrs. J. F. Bigelow, and Mr. and Mrs. Thomas Burke, Marlboro, Mass.; Mrs. L. D. Thorpe, West Medford, Mass.; Miss Alice S. Corner, Miss Catherine Sullivan, and Mrs. T. J. Carmody, Holyoke, Mass.; Mrs. John Mayo, Bridgewater, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Mrs. George E. Winslow and Mr. C. H. Mann, Waltham, Mass.; Mrs. G. R. Payson and Master Payson, Belmont, Mass.; Master Eldredge, Onset, Mass.; E. S. Horton, M. F. Ashler, George M. Morrell, F. C. Waugh, and J. T. Inman, Attleboro, Mass.; Mrs. F. J. Gifford, and Mr. and Mrs. J. J. Kirby, Fall River, Mass.; Mrs. F. H. Gunther, Dracut, Mass.; Mrs. George T. Staples and Mrs. J. E. Smith, Dedham, Mass.; Mrs. R. Wetherbee, Marblehead, Mass.; Mrs. W. E. Maybury, Braintree, Mass.; Mrs. M. E. Phillips, Weymouth, Mass.; J. Burns, Everett, Mass.; David H. Sullivan, Lowell, Mass.; Mrs. F. C. Kimball, Miss Florence C. Kimball, Mrs. E. M. Shedd, Mrs. H. E. Browne, Mrs. F. L. Fuller, Mrs. J. G. Lufkin, Miss Joan M. Ham, and Mr. A. D. Stevens, of *Municipal Journal and Engineer*, Boston. — 46.

A business meeting of the Association was held in the afternoon on the steamer *King Philip* en route from Nahant to Boston. President Thomas in the chair and Mr. C. W. Sherman elected Secretary *pro tem.*

The following-named applications for membership were read by the Acting Secretary.

Elliot S. Tucker, water commissioner, Winchendon, Mass.; Charles R. Henderson, manager water works, Davenport, Ia.; Francis T. Kemble, superintendent New Rochelle Water Company, New Rochelle, N. Y.; W. P. Robinson, general manager Denver Union Water Company, Denver, Colo.; J. H. Ayres, superintendent of water supply and sewers, Manila, P. I.

For associate membership, Frank E. Davis, Boston, Mass.

On motion it was unanimously voted that the Acting Secretary cast the ballot of the Association for all the applicants. This having been done, they were declared elected.

Adjourned.

C. W. Sherman, *Acting Secretary.*

Twenty-Eighth Annual Convention.

New York City,
September 8, 9, and 10, 1909.

The Twenty-Eighth Annual Convention of the New England Water Works Association was held in New York City on September 8, 9, and 10, 1909. The headquarters of the Association were at the Park Avenue Hotel, and the meetings were held in the assembly hall of the hotel.

The following members and guests were in attendance:

Honorary Members.

Rudolph Hering, F. W. Shepperd, and Frederic P. Stearns. — 3.

Members.

S. A. Agnew, Kenneth Allen, J. M. Anderson, M. N. Baker, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, Edward Bartow, G. B. Bassett, G. W. Batchelder, E. W. Bemis, F. D. Berry, C. R. Bettes, J. M. Betton, F. K. Betts, F. E. Bisbee, Albert Blauvelt, C. A. Bogardus, R. W. Bogart, Jr., C. L. Bowker, D. S. Brinsmade, W. W. Brush, James Burnie, E. W. Bush, T. J. Carmody, C. E. Chandler, G. L. Chapin, J. H. Child, C. E. Childs, S. K. Clapp, E. W. Clarke, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, G. K. Crandall, C. E. Davis, J. M. Divin, John Doyle, M J. Doyle, W. G. Dryden, E. R. Dyer, G. G. Goodell, E. D. Eldredge, R. N. Ellis, L. N. Farnum, E. A. Fisher, A. D. Flinn, Richard J. Flinn, John H. Flynn, A. P. Folwell, Halsey French, G. W. Fuller, William B. Fuller, S. DeM. Gage, F. J. Gifford, D. H. Gilderson, A. S. Glover, W. B. Goentner, J. W. Graham, Charles A. Hague, R. K. Hale, F. E. Hall, R. J. Harding, W. H. Hart, E. L. Hatch, W. C. Hawley, A. B. Hill, N. S. Hill, Jr., W. R. Hill, B. B. Hodgman, H. G. Holden, W. D. Hubbard, D. D. Jackson, G. A. Johnson, W. E. Johnson, J. W. Kay, G. G. Kennedy, E. W. Kent, Willard Kent, F. C. Kimball, A. C. King, G. A. King, F. T. Kemble, J. J. Kirkpatrick, Morris Knowles, B. C. Little, F. H. Luce, J. L. Ludlow, Daniel MacDonald, H. S. R. McCurdy, T. H. McKenzie, Hugh McLean, J H. McManus, H. B. Machen, H. V. Macksey, W. M. Marple, A. E. Martin, W. P. Mason, G. F. Merrill, Leonard Metcalf, E. E. Minor, H. T. Murphy, A. S. Negus, J. A. Newlands, F. L. Northrop, Alexander Orr, J. C. Otis, H. D. Pease, E. M. Peck, E. L. Peene, T. A. Peirce, E. B. Phelps, A. E. Pickup, W. D. Pollard, C. DuB. Pollock, Alexander Potter, Clyde Potts, R. W. Pratt, F. L. Rector, A. A. Reimer, G. S. Rice, W. H. Richards, Robert Ridgway, Henry Roberts, Jas. F. Sanborn, P. R. Sanders, W. J. Sando, A. L. Sawyer, W. Scranton, S. P. Senior, E. M. Shedd, J. E. Sheldon, M. A. Sinclair, H. O. Smith, J. W. Smith, P. S. Smith, G. H. Snell, H. T. Sparks, J. F. Sprenkel, G. T. Staples, G. A. Taber, H. L. Thomas, R. J. Thomas, W. H. Thomas,

J. L. Tighe, J. A. Tilden, D. N. Tower, L. L. Tribus, A. S. Tuttle, E. S. Tucker, E. L. Walker, J. H. Walsh, R. S. Weston, G. C. Whipple, J. C. Whitney, F. I. Winslow, G. E. Winslow, F. E. Winsor, I. S. Wood, T. Woodruff, L. C. Wright, — 162.

Associates.

Anderson Coupling Company, by C. E. Pratt; Harold L. Bond & Co., by George S. Hedge; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edw. F. Hughes, T. P. Morrissey, and Frank Barry; Darling Pump and Manufacturing Company, by Hubert Thorp, J. L. Hough, and D. J. Slone; East Jersey Pipe Company, by E. E. Mentzer; The Fairbanks Company, by Charles H. White; Glauber Brass Manufacturing Company, by A. C. Fisher and Samuel Davis; F. H. Hayes Machinery Company, by T. J. Nagle and Charles E. Mueller; Hersey Manufacturing Company, by William C. Sherwood, Weldon D. Griffin, Walter Hersey, J. A. Tilden, Albert S. Glover; International Steam Pump Company, by Samuel Harrison, J. Watson Sims, A. H. Braidwood, F. J. Swenson, and F. J. Smith; Jenkins Brothers, by W. G. L. Compte; Kennedy Valve Company, by William Martin, George H. Steiner, and Daniel Kennedy; Lead Lined Iron Pipe Company, by T. E. Dwyer and J. W. McComack; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by F B. Mueller and O. B. Mueller, Arthur C. Pilcher, F. W. Cruikshank, G. A. Caldwell, and E. W. Aubueger; National Lead Company of Massachusetts, by Edward B. Hanson and G. D. Dorsey; National Meter Company, by W. P. Oliver, J. G. Lufkin, George D. MacVeagle, H. L. Weston, and C. H. Baldwin; National Water Main Cleaning Company, by D. H. Buel; Neptune Meter Company, by F. A. Smith, C. A. Vaughan, H. H. Kinsey, and T. D. Faulks; New York Continental Jewell Filtration Company, by A. E. Milligan; New York Lead Wool Company, by H. M. Hein; Pittsburg Meter Company, by T. C. Clifford, V. E. Arnold, W. Lockwood, and F. L. Northrop; Rensselaer Manufacturing Company, by Charles L. Brown and J. S. Warde, Jr.; Ross Valve Manufacturing Company, by William Ross and Adam Ross, 2d; John Simmons Company, by Thomas V. Foster; Standard Water Meter Company, by J. V. Da Silia; A. P. Smith Manufacturing Company, by F. N. Whitcomb and D. F. O'Brien; Thomson Meter Company, by J. L. Atwell, E. M. Shedd, W. S. Cetti, Henry G. Folger; Union Water Meter Company, by C. L. Anderson, F. E. Hall, and Edw. P. King; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; Water Works Equipment Company, by W. H. Van Winkle, Jr., and W. H. Van Winkle; R. D. Wood & Co., by William Woodburn and Charles R. Wood. — 77.

Guests.

Hermon L. Hover, Brunswick, Me.; E. B. Dyer, Portland, Me.; Mrs. E. L. Wallace, Miss Josie C. Hardy, Mr. and Mrs. W. H. Davenport, Mr. and Mrs. George A. Stewart, Franklin, N. H.; George Goodhue, Concord, N. H.; Mrs. P. S. Smith, Montpelier, Vt.; Thomas P. Taylor, Mrs. Frank C. Kimball, Miss

Florence E. Kimball, Mrs. Frederic I. Winslow, Mrs. R. J. Flinn, Mrs. Samuel Harrrison, Mrs. Fred P. Stearns, M. S. Kaharl, Charles T. Merrill, E. A. Collins, Frederic H. Fay, Boston, Mass.; Mrs. E. D. Eldredge, Master Neddie Eldredge, Onset, Mass.; Mrs. Edw. M. Shedd, Somerville, Mass.; Miss J. A. Osgood, Mrs. F. H. Hall, Mrs. D. H. Gilderson, Haverhill, Mass.; Mrs. DeM. Gage, Mr. and Mrs. G. G. Desmond, A. H. Marsden, Lawrence, Mass.; John F. Monahan, Revere, Mass.; Mrs. G. T. Staples, Dedham, Mass.; Mrs. A. E. Martin, Springfield, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. W. H. Thomas, Hingham, Mass.; Joseph F. Biladeau, Pittsfield, Mass.; Dr. and Mrs. John T. Collins, Whitman, Mass.; Joseph Alger, Brockton, Mass.; Mrs. T. J. Carmody, Mrs. M. J. Doyle, Holyoke, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Mr. and Mrs. J. P. Bacon, Cambridge, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. I. S. Wood, Providence, R. I.; Mrs. Thomas A. Peirce, Mrs. Emma T. Vaughan, East Greenwich, R. I.; Mr. and Mrs. H. R. Cooper, Mr. and Mrs. C. A. Goodhue, Thompsonville, Conn.; Mrs. Elliot S. Tucker, Winchendon, Mass.; Mr. and Mrs. J. B. Longley, Lewiston, Me.; E. J. Mehren, Robert K. Tomlin, I. S. Holbrook, *Engineering Record;* Thaddeus Merriman, Mrs. H. B. Machen, Edward Kloberg, M. Blatt, I. M. de Varona, Mrs. Kenneth Allen, Mrs. F. W. Shepperd, F. M. Griswold, J. T. Morris, F. S. Buckley, Mrs. C. D. Pollock, Charles Warren Hunt, Mrs. Edward B. Hanson, New York City; G. N. Durland, Mrs. Charles R. Bettes, Far Rockaway, N. Y.; Thomas C. Atwood, Mrs. Edward L. Peene, Yonkers, N. Y.; Mrs. J. H. Rapp, Mr. and Mrs. C. H. Chambers, S. E. Cole, White Plans, N. Y.; Mrs. O. B. Mueller, New Rochelle, N. Y.; Mrs. W. P. Oliver, Miss M. G. Oliver, William H. Garrison, H. J. McMahon, Master William Cetti, Frank E. Hale, T. Wilbur Melia, Brooklyn, N. Y.; Charles K. Bassett, Buffalo, N. Y.; Mrs. F. H. Luce, Woodhaven, N. Y.; H. A. Holmes, Waterford, N. Y.; Mrs. Charles H. White, Jamaica, L. I.; William Duncan, Middletown, Conn.; Miss Theta Helen Baker, Montclair, N. J.; E. Christophersen, W. D. Agnew, Roswell M. Roper, East Orange, N. J.; William H. Blair, West Orange, N. J.; Mr. and Mrs. W. Paulison, Passaic, N. J.; Miss May I. Agnew, J. W. Griffin, Mrs. R. A. Nemmo, Edw. W. Henry, Jersey City, N. J.; H. L. Boyer, Trenton, N. J.; Mrs. H. Mueller, Mrs. F. W. Cruickshank, Decatur, Ill.; George R. Taylor, Scranton, Penn.; Dr. and Mrs. W. S. Rankin, Raleigh, N. C.; M. H. Urban, Birmingham, Ala.; W. Dart, Montreal, Que. — 112.

On Tuesday evening there was a reception in the parlors of the Park Avenue Hotel, given by the resident members to the members and guests attending the convention.

Morning Session, Wednesday, September 8.

President Robert J. Thomas called the convention to order and spoke as follows:

"We have with us to-day, to welcome the members of the New

England Water Works Association to New York, a gentleman who in the past has been identified very closely with the water works systems of New England, acting in an engineering capacity on several of our most important works, including those at New Bedford, Lowell, and Boston, and who for many years has been connected with the great Croton water-works system of New York City. He is now engineer of subway construction in New York, and is the chairman of the Committee of Arrangements for this convention. It gives me great pleasure to present to you Mr. George S. Rice, of New York City."

Mr. George S. Rice. *Ladies and Gentlemen:* It is with pleasure that I greet you at the twenty-eighth convention of the New England Water Works Association. I recollect distinctly your last convention here in New York, how we took you around and tried to make it pleasant for you, and it has been the endeavor of the committee at this time to arrange such a program that the members will not only find plenty of mental stimulus, but will also have abundant opportunity to look around New York, where there is so much to see.

Mr. Rice then made the announcements for an excursion to Coney Island, a visit to the Pennsylvania Railroad terminal, a trip through the tunnels of the Manhattan & Hudson Railway Company from Twenty-eighth Street to Hoboken, Jersey City, Cortlandt Street, New York, and return, and a trip to the Ashokan reservoir of the Catskill water supply system under construction by the city of New York. In closing, on behalf of the committee, he bade the members of the Association a hearty welcome to the city, and repeated his assurances that the committee would be glad to do all in their power to make the convention pleasant and profitable.

The President. The committee certainly gave us a demonstration last night, at the reception, of what we may expect, and in behalf of the Association I wish to express our appreciation of the committee's work. We are fortunate in having on the committee men of such prominence and large experience and ability, and especially fortunate in having Mr. Rice as chairman of the committee. I wish to thank him personally and on behalf of the Association for the interest he has taken in the

arrangements. We will now proceed with the business of the convention.

The Secretary read the following list of applications for membership:

Active: John J. Philbin, superintendent Clinton Water Department, Clinton, Mass.; I. M. de Verona, chief engineer Water Supply, Gas, and Electricity, New York; Grandville R. Jouet, Washington, D. C., chief chemical and assistant superintendent of the Washington Aqueduct Filtration Plant; Edward E. Minor, New Haven, Conn., engaged in water supply engineering and construction work; Edward Kloberg, New York City, assistant engineer Catskill Aqueduct Project, High Pressure Fire Service, Bureau of Manhattan; Max Blatt, New York City, assistant engineer High Pressure Fire System, Department of Water Supply, New York; M. R. Cooper, Thompsonville, Conn., superintendent Water Company.

Associate: New York Lead Wool Company; Gamon Meter Company, Newark, N. J.; Standard Water Meter Company, Brooklyn, N. Y.; Glauber Brass Manufacturing Company, Cleveland, Ohio; Frank E. Davis, Worcester, Mass., New England agent for Mietz & Weiss oil engines.

On motion of Mr. Bancroft, the Secretary was authorized to cast the ballot of the Association in favor of the applicants whose names had been read, and he having done so, they were declared duly elected members of the Association.

On motion of Secretary Kent, the President was authorized to appoint a committee of five to nominate officers for the ensuing year. The following-named gentlemen were appointed as the committee: Frederic P. Stearns, Boston; J. Waldo Smith, New York; William F. Sullivan, Nashua, N. H.; Charles W. Sherman, Boston; Alfred E. Martin, Springfield.

Mr. William W. Brush, engineer of distribution, New York City, then read a paper on "The New York Water Supply." Remarks were made by Mr. William Dart, Mr. Alfred D. Flinn, Prof. Edward W. Bemis, Dr. John C. Otis, and Michael F. Collins.

Mr. James L. Tighe, city engineer, Holyoke, Mass., read a paper entitled "Odors and Tastes in the Water Supply of Holyoke," which was discussed by Prof. William E. Mason, Edward Bartow, W. C. Hawley, and Leonard Metcalf.

Adjourned.

MORNING SESSION, THURSDAY, SEPTEMBER 9.

President Thomas in the chair.

Charles E. North, Montclair, N. J., consulting sanitary expert in water and milk work, was elected an active member, and John Simmons Company, water works supplies, New York City, an associate member.

Mr. H. O. Lacount, for the Committee to Prepare a Standard Specification for Fire Hydrants, sent the following letter, which was read by the Secretary.

BOSTON, MASS., September 7, 1909.

Mr. WILLARD KENT, *Secretary New England Water Works Association*,
PARK AVENUE HOTEL, NEW YORK, N. Y.

Dear Sir, — I find that, due to a previous important engagement, I shall not be able to attend the convention in New York this week, and, therefore, cannot present the report of the Hydrant Committee in person. I have been in communication with the other members of the committee, with the exception of Mr. Gow, and find that neither Mr. Sullivan, Mr. Stacy, nor Mr. McInnes will probably be at the convention.

As the report is not considered by the committee to be in shape for final action. and would be presented merely for discussion, we believe it is very desirable that at least two or three of the committee be present in order to get directly the ideas of the members of the Association on whatever points may be discussed, and also to be able to ask questions of the members with the view of obtaining further data for the guidance of the committee. Moreover, the committee are of the opinion that better results would be obtained from such a discussion if held at one of the regular meetings in Boston, where there would probably be more time for the full consideration of the report than at the New York convention, when other matters of more immediate interest are taking attention. The committee would, therefore, ask that you report for them progress, leaving the presenting of the specifications in detail to a later meeting.

However, I enclose herewith for the committee the proposed specifications, which you are at liberty to present if you still consider this advisable. We trust, however, that you will find it feasible to hold the report until a later date.

Yours truly,

(Signed) H. O. LACOUNT, *Chairman*.

MR. GRISWOLD. I was quite interested, Mr. President, in the proposition that there was to be brought up here the question of standardizing hydrants for fire service. The National Fire Protection Association has a committee having that matter in charge,

and it is a very important matter. I am not chairman of that committee, but I am a member of it, and it is my idea that cooperation in relation to the establishment of a standard will be very wise, rather than that either organization alone should take up the subject and reach a conclusion by itself. My purpose in coming here was to suggest that our committee will be very glad indeed to coöperate with the committee of the New England Water Works Association, not in the way of a coalition of the committees, because they are from two different organizations, but to give all the information we can and to absorb all the information we can, and between the two of us reach a conclusion which will have wider influence than the action of either organization alone. What I have said may be taken as representing the views of our committee.

Dr. John C. Otis, of Poughkeepsie, N. Y., read a paper on "The Poughkeepsie Water Works." Messrs. Alexander Potter, Earle B. Phelps, and Edward Bartow participated in the discussion.

The President called for the report of the Committee to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country. Mr. M. N. Baker, chairman of the committee, responded as follows:

"Mr. President, the report of this committee will not be much longer than its name. It has practically nothing to report which has not already been made public throughout the length and breadth of the country, not only through official papers, but through the daily press. Conservation is 'in the air'; it is not only being discussed, but some little achievement is being made in the way of attempts toward the conservation of our national resources; a large number of state conservation agents have been appointed, and much general attention is being given to this important subject. That is all that the committee has to report at present."

Evening Session, Thursday, September 9.

President Thomas presiding.

William Dart, of Montreal, formerly engaged in laying water supplies in various places in England; Frank W. Green, of Little

Falls, N. J., superintendent of the Little Falls Works, East Jersey Water Company, and Lucian Buck, chief engineer Champion Fiber Company, with practice as designing and consulting engineer of water and sewer systems, were elected to membership.

The first business on the program for the evening was the report of the Committee to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association or other organization of mill owners, leading to the formulation of standard rules and methods of computing for assessing damages for the diversion of water. In the absence of the chairman of the committee, a report was made by Mr. Leonard Metcalf, as follows:

" I am sorry to say, Mr. President, that Mr. Main, the chairman of the committee, is not able to be present to-night, and he has asked me to make a report for the committee. Our report at this time will be very short, but as the committee is anxious to be continued in order to complete its work, and finds itself unable to make a final report at this time, it seems fitting that we should make at least a verbal statement of progress to date, for the committee hopes that you will not assume that it has allowed the matter to lapse.

" As you all know, we sent out a preliminary circular asking for information as to any settlements which have been made, and we followed that by a second one, and subsequently personal letters were sent out to water-works superintendents and engineers from the Atlantic to the Pacific slope, asking them kindly to contribute any data they might have along these lines. I am glad to be able to report that we have had a reasonably hearty response to those letters, and at the present time we have a little over one hundred reports in considerable detail as to awards for settlement in water cases. Those we have abstracted and tabulated and the data will be presented to you in detail and in summarized form, we hope at one of the winter meetings. We are still hoping, however,.to get additional material from some twelve or fifteen men of large experience in these matters, who have volunteered to give us their material, or such of it as they could conveniently arrange, if we could give them more time. We shall be glad, of

course, to get as much of that material as possible before the report as a whole is presented.

" It has also been suggested that it might round out the subject and be of interest to the members if we could get some competent lawyer to present a paper or write an introduction for the report bearing upon the legal phases of the matter; and the committee still hopes that it may be able to arrange for this, although we cannot assure you at this time that we shall have such a paper. When the material is finally in shape, the report will be rather voluminous, and we shall ask the Secretary if it may not be published in advance of the meeting, and then presented to you at the meeting merely in outline, so that you may discuss the contents of the report without being bored by any attempt on our part to read it in detail at the meeting.

" For these reasons your committee would be glad to be continued until it can present its report to you in proper form."

On motion of Mr. Frank C. Kimball, the committee's report was accepted as a report of progress and the committee continued.

A paper on " Disinfection as an Adjunct to Water Purification," by H. W. Clark, chemist Massachusetts State Board of Health and Stephen de M. Gage, biologist Massachusetts State Board of Health, was read by Mr. Gage and discussed by Mr. Robert J. Harding, Mr. Leonard Metcalf, Mr. Alexander Potter, Mr. Morris Knowles, Mr. M. N. Baker, and Dr. John C. Otis.

A paper by Henry A. Young, C. E., Yonkers, N. Y., on " Camaguey (Cuba) Water Works," was presented by its title.

On motion of Professor Bemis, the convention was adjourned.

EXECUTIVE COMMITTEE.

JUNE 18, 1909.

A meeting of the Executive Committee was held on the *King Philip*, en route from Nahant to Boston at 3.30 o'clock P.M. to-day. There were present President R. J. Thomas and members George W. Batchelder, Richard K. Hale, George A. King, Charles W. Sherman, and George A. Stacy. President Thomas in the chair. Mr. C. W. Sherman was elected Secretary *pro tem.*

Applications for membership were considered as follows: Elliot S. Tucker, water commissioner, Winchendon, Mass.; Charles R. Henderson, manager water works, Davenport, Ia.; Francis T. Kemble, superintendent New Rochelle Water Company, New Rochelle, N. Y.; W. P. Robinson, general manager Denver Union Water Company, Denver, Colo.; J. H. Ayres, superintendent water supply and sewers, Manila, P. I.

For associate membership, Frank E. Davis, Boston, Mass.

Voted unanimously to recommend to the Association the election of the above-named applicants to the classes for which they have applied.

The committee then took into consideration the proposal of the Water Works Manufacturers Association, tendered by Mr. James A. Tilden, chairman, manager of the Hersey Manufacturing Company of Boston, which proposal had been made to the committee by Mr. Tilden at an informal meeting of the committee on the trip to Nahant. Said proposal of the Water Works Manufacturers Association was to furnish entertainment at our annual convention with the understanding that the Manufacturers Association should have the privilege of furnishing and controlling the distribution of the badges at our annual convention and should also have the privilege of controlling and managing the exhibits made at the convention. After due consideration it was unanimously voted that the Association prefers not to ask for or receive any courtesy of the kind or magnitude contemplated by the Water

Works Manufacturers Association, and that Mr. Kent and Mr. Sherman be a committee to convey to the representative of the Manufacturers Association this decision.

Adjourned.

C. W. Sherman, *Acting Secretary.*

Meeting of the Executive Committee of the New England Water Works Association held at the Park Avenue Hotel, New York City, September 8, 1909.

Present: President Robert J. Thomas and members George A. Batchelder, George A. King, E. W. Kent, William C. Hawley, Ermon M. Peck, Lewis M. Bancroft, and Willard Kent.

The following applications were received and recommended for membership, viz.:

John J. Philbin, superintendent water department, Clinton, Mass.; Edward E. Minor, New Haven, Conn.; H. R. Cooper, superintendent Water Company, Thompsonville, Conn.; I. M. deVerona, chief engineer Department Water Supply, Gas and Electricity, New York City; Grandville R. Jones, chief chemist and assistant superintendent Filtration Plant, Washington, D. C.; Edward Kloberg, assistant engineer High Pressure Fire Service, Borough of Manhattan, New York City; Max Blatt, Department Water Supply, City of New York, N. Y.; Lucien Buck, consulting engineer, Canton, N. C.; Charles E. North, consulting sanitary expert, New York City; Frank W. Green, superintendent Little Falls Works, Little Falls, N. J.; William Dart, Montreal, Canada, and from Gamon Meter Company, Newark, N. J.; Glauber Brass Manufacturing Company, Cleveland, Ohio; New York Lead Wool Company, New York City; John Simmons Company, New York City; and Standard Water Meter Company, of Brooklyn, N. Y.

Adjourned.

Willard Kent, *Secretary.*

OBITUARY.

Carroll Fitch Story, resident engineer of the Connecticut River pipe crossing of the new Little River Water Supply for Springfield, Mass., died at the Springfield Hospital, October 19, 1909.

Mr. Story was born at Milwaukee, Wis., in 1884. He graduated in 1905 from Beloit College, the same fall entering the Massachusetts Institute of Technology, from which he graduated in 1907 from the Sanitary Engineering course. Immediately following his graduation he accepted a position with the Springfield Water Department in charge of the operation of the Ludlow Intermittent Filters.

Many of the members of this Association will remember him at the time of their visit to this filter plant at the time of the annual convention, and again at a later date, when he spoke to the Association on the operation of these filters.

Since this time he has occupied other responsible positions in connection with the construction of the new water supply for Springfield, and was at the time of his death resident engineer on the construction of the two submerged 30-inch pipes which are being laid under the Connecticut River.

Mr. Stoiy was elected a member of the New England Water Works Association September 11, 1907.

ATER WORKS ASSOCIATION.

.GANIZED 1882.

ecember, 1909. No. 4.

esponsible for the statements or opinions of any of its members.

CITY WATER SUPPLY.

NGINEER OF DISTRIBUTION, BOARD OF SUPPLY, NEW YORK.

ad September 9, 1909.]

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BOROUGHS OF MANHATTAN AND THE BRONX.

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ERRATUM.

1909, September Journal, Vol. XXIII, No. 3.

Page 256, Table 1, eighth column, in heading read (CO_3) instead of "(CO_2)."

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXIII. December, 1909. No. 4.

NEW YORK CITY WATER SUPPLY.

BY WILLIAM W. BRUSH, ENGINEER OF DISTRIBUTION, BOARD OF WATER SUPPLY, NEW YORK.

[*Read September 9, 1909.*]

The present city of New York is divided into the boroughs of Manhattan, Brooklyn, The Bronx, Queens, and Richmond, these boroughs, with the exception of Manhattan, being made up of many communities which, prior to consolidation, were incorporated as villages, towns, and cities. About twenty-five separate systems of water supply served the territory covered by Greater New York, and practically all these systems are still in use. To give, in this paper, an intelligent idea of the New York water supply, only the large systems can be described in any detail, and borough lines will be the basis of division. As one supply is used for Manhattan and a portion of The Bronx, these boroughs will be taken together, and Brooklyn, Queens, and Richmond treated separately.

The new supply from the Catskills is the first system that has been designed to supply water to all the boroughs comprising the greater city and will practically cross-connect all the existing systems.

BOROUGHS OF MANHATTAN AND THE BRONX.

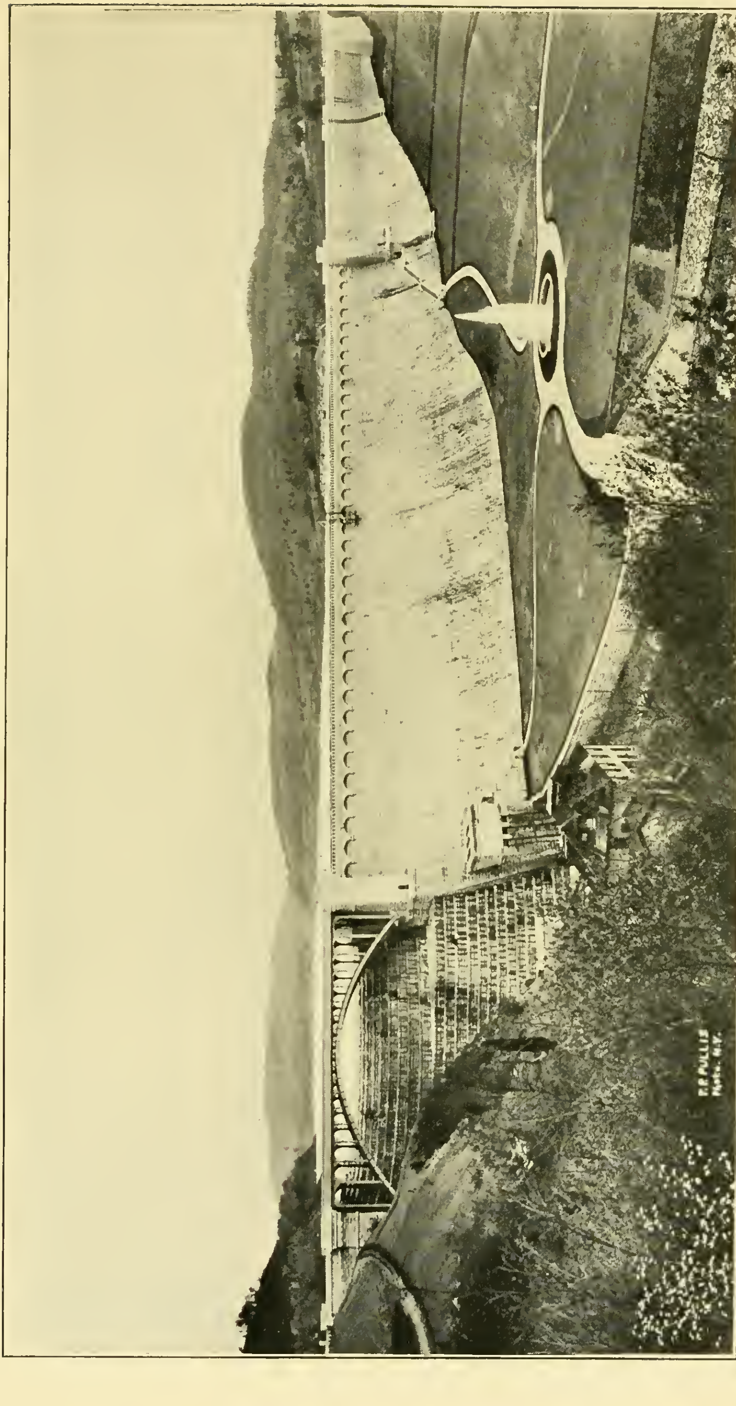
During the latter part of the eighteenth and the early part of the nineteenth centuries, several attempts were made to furnish a water supply from wells on Manhattan Island, but the quantity and quality of the water were so unsatisfactory that the introduction of a water supply system for what is now the Borough of

Manhattan may be properly said to date from 1842, when water from the Croton River was first utilized, the population at that time being about three hundred and fifty thousand. This supply was supplemented by an emergency supply from the Bronx and Byram rivers, the Bronx supply being introduced in 1884, and the Byram in about 1897. The available supply from the Croton River was greatly increased by the construction of the new Croton aqueduct, which was put into service in 1890, and by the extension of the Croton Reservoir system, which is still in progress.

The Croton supply is taken from the Croton River, which lies about 30 miles to the north of New York City and discharges into the east side of the Hudson River. The watershed is hilly, having a comparatively impervious soil, and is rather sparsely settled, except in the immediate vicinity of several thriving villages located within the boundaries of the drainage area. The total tributary area is 360 square miles, of which about 19.3 square miles are water surface. The main dam, known as the New Croton Dam, is constructed across the valley about 6 miles from the point where the river joins the Hudson. This dam is of rubble masonry, faced with ashlar, having its foundation on rock, the lowest point of the foundation being 123 feet below the river bed, which at this point is 173 feet below the top of the dam. The crest of the spillway is at an elevation* of 196 for 250 feet, and at an elevation of 200 for the remaining 750 feet. The water level can be raised by flashboards to an elevation of 202, the top of the dam being at elevation of 210. The dam, including a spillway of 1 000 feet, is 2 168 feet long and contains about 850 000 cubic yards of masonry. Construction was commenced in 1892 and the works sufficiently completed to be used in 1905. The total cost, including land, was about $15 000 000. The reservoir formed by this dam is 20 miles long and has a storage, at the spillway level, of nearly 38 000 m. g.,† of which about 31 000 m. g. are above the invert of the aqueduct, and, therefore, ordinarily available. The original, or Old Croton Dam, which is located about 3 miles above the new dam, is flooded by this reservoir to a depth of 34 feet.

* All elevations given refer to the datum used for the respective systems. The datum for the Board of Water Supply is mean sea level at Sandy Hook, which is 0.5 feet above the Croton datum and 1.7 feet below the Brooklyn datum.

† m. g. stands for "million gallons" and m. g. d. for "million gallons daily."



THE NEW CROTON DAM AND RESERVOIR.

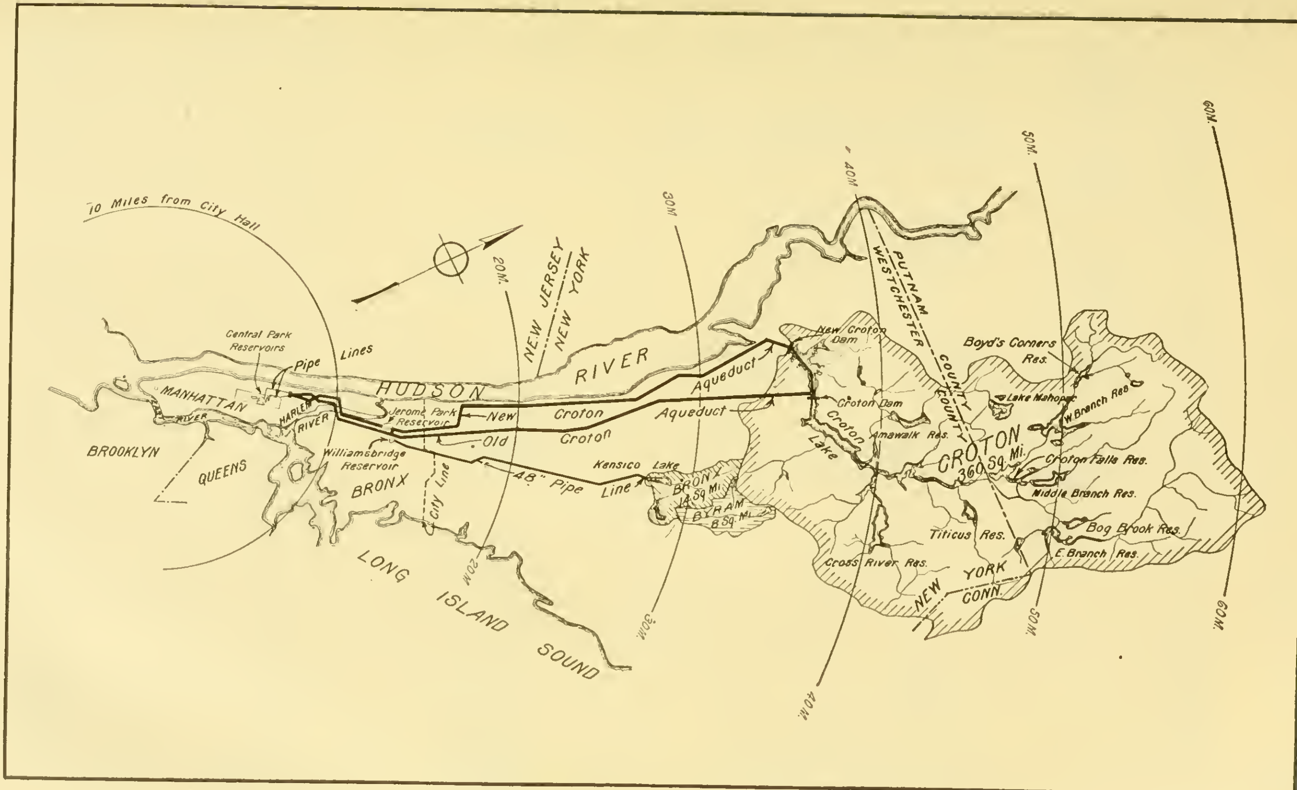


Fig. 1. Croton, Bronx and Byram Watersheds, showing Reservoir, Aqueduct, and Pipe Lines.

TABLE No. 1.

Reservoirs on Croton, Bronx and Byram Watersheds.

Name.	Year when First Utilized.	Elevation of Spillway. Feet.	Water Surface. Sq. M.	Storage, including Flash-boards. M. G.	Tributary Watershed. Sq. M.
		Croton.			
Old Croton	1842	166	0.760	2 000	339
Boyd's Corners	1873	600	0.436	2 730	21
Middle Branch	1878	380	0.672	4 160	21
East Branch	1891	417	0.898	5 240	73
Bog Brook	1891	417	0.640	4 400	4
Titicus	1893	325	1.103	7 620	23
West Branch	1895	503	1.560	10 730	41
Amawalk	1897	400	0.940	7 090	71
New Croton	1905	200	5.574	26 110†	360
Muscoot	1905	200		5 700	...
Cross River	1908	330	1.310	10 920	29
Croton Falls	Under construction	310	1.910	15 780	100
Fourteen natural ponds	1870	...	.....	2 060	...
Total			19.32*	104 540	
		Bronx and Byram.			
Lake Kensico	1884	250	0.39	1 797	22
Byram diverting reservoir	1897	...	0.12	180	8
Byram Lake	1897	...	0.25	664	...
Rye Ponds	1884	301	0.44	1 440	...
Wampus Lake	....	...	0.08	60	...
Total				4 141	

An auxiliary dam, called the Muscoot dam, has been built to hold the water in the upper end of the New Croton Reservoir when the water in the main portion of the reservoir is drawn down, to avoid exposing large areas where the water is shallow when the reservoir is full. Eight auxiliary reservoirs have been formed by masonry dams and earthern dikes, constructed on the various tributary streams and branches. The stored water in these reservoirs is

* Includes all ponds on watershed. There are 28 ponds in addition to those noted above, or a total of 52.

† There are 6 123 m. g. in the Croton Reservoir below the aqueduct level, and, therefore, not available without pumping. This storage is not included in the contents as given.

discharged, as required, into the natural water courses and allowed to flow to the main reservoir. Fourteen lakes and ponds are also utilized to some extent for storage.

The Croton Falls Reservoir, which is now under construction, will give an additional storage reservoir on what is known as the west branch of the Croton River, and a diverting dam and channel will convey water from the east branch into this reservoir. Upon the completion of this reservoir, the total available storage, including that obtained by flashboards, will be about 105 000 m. g., which is equivalent to 290 m. g. per square mile of watershed.

The yearly rainfall on the Croton watershed averages about 48 inches, and the estimated safe minimum yield, based on the stream flow as measured since 1868, and assuming the completion of the Croton Falls reservoir, is 336 m. g. d., which is equivalent to 930 000 gallons per square mile of watershed. With the present large water surface the evaporation exceeds at times the minimum monthly flow.

There are two aqueducts available to convey the water to the city, the intake being at a large gatehouse located just below the Old Croton dam. These aqueducts are known as the " Old " and " New " Croton, respectively. The Old Croton Aqueduct has its invert at elevation of 153, having, in general, interior dimensions of 7½ feet wide by 8 feet high, giving a cross-section of about 53 square feet. Its slope is 1.1 feet per mile, with a capacity of about 80 m. g. d. The aqueduct is 34 miles long, of which 4 miles are in earth or rock tunnel, the remainder being cut-and-cover section. The New Croton Aqueduct has its invert at elevation of 140, is usually of horseshoe shape, 13.6 feet wide and 13.5 feet high, with an area of 154 square feet. The slope is .7 foot per mile and it has a capacity of 300 m. g. d. The aqueduct is almost wholly in rock tunnel, it is brick lined and is 31 miles long, of which only a little over 1 mile is cut-and-cover. The total aqueduct capacity for the Old and New Croton is slightly less than 400 m. g. d.

The aqueducts are now connected to a large receiving and equalizing reservoir, known as the Jerome Park Reservoir, which is located at the southerly end of Van Cortlandt Park, about 3 miles south of the city line, and to the west of Jerome Avenue. This reservoir is divided into two basins, the westerly one having been

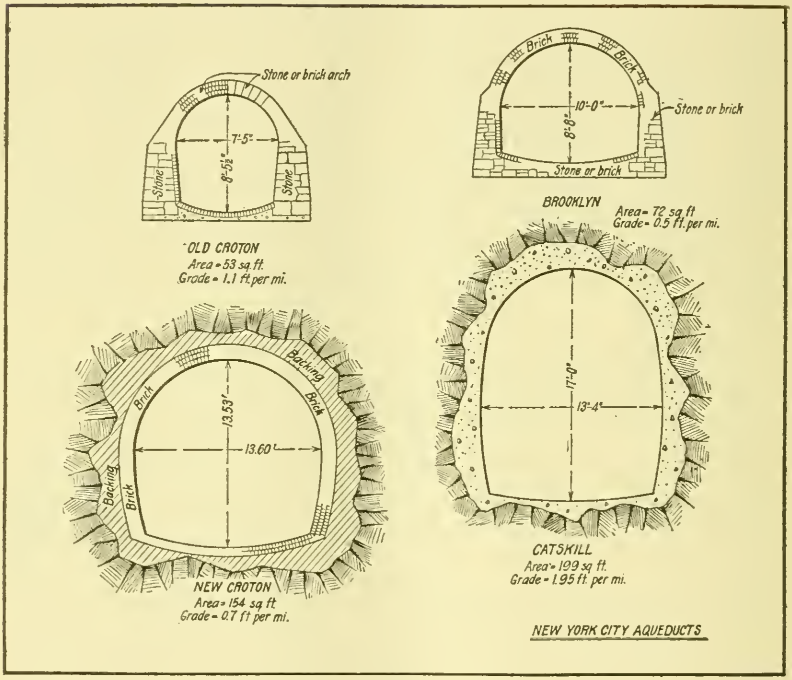


FIG. 2. TYPICAL SECTIONS OF CROTON AQUEDUCTS.

With the maximum section of Brooklyn aqueduct and grade tunnel section of the Catskill aqueduct. The Catskill and New Croton sections are for grade tunnel.

sufficiently completed to put into use in 1905. After the greater part of the excavation for the easterly basin was completed, it was decided to suspend construction, in anticipation that this basin would be used in connection with a future filtration plant for the Croton supply. The reservoir has a flow line at elevation of 134, the bottom elevation being about 107. The west basin has an area of 94 acres and a capacity of about 770 m. g., while the east basin has 50 per cent. greater area.

The Old Croton aqueduct, which previously passed through the site of the west basin, has been diverted within the limits of the basin to a new aqueduct built through the dividing wall, and continues in cut-and-cover to the Harlem River, where it crosses in one 7-foot and two 3-foot pipes over an imposing masonry arch bridge known as High Bridge. The cut-and-cover section is continued to a gatehouse at Amsterdam Avenue and 135th Street, constructed at the time when the New Croton Aqueduct was built. The New Croton Aqueduct drops rapidly just north of the Jerome Park Reservoir into a circular brick-lined tunnel 12.25 feet in diameter, with invert 7.6 feet above tide water. A branch aqueduct connects the main aqueduct with the reservoir, and the water from the reservoir can flow into the tunnel through a downtake shaft connected to the central gatehouse. At the Harlem River the tunnel drops through a shaft to an elevation of about 300, the diameter reducing to 10 feet. On the west side of the Harlem River the tunnel is brought up a vertical shaft to elevation of 13.5, provision being made to pump out the tunnel from this shaft, and continues with an upward gradient to elevation of 21.6 at the uptake shaft at the 135th Street gatehouse. The pressure on this tunnel varies from about 50 pounds per square inch for the land section to nearly 200 pounds per square inch, or about 450 feet, for the river section. The pressure tunnel section, which is 36 000 feet long, showed a leakage of 228 000 gallons per twenty-four hours when tested upon completion. From the gatehouse the water is carried mainly in 48-inch cast-iron mains, to the distribution system and to the distributing reservoirs in Central Park.

These distributing reservoirs consist of three basins, the two southerly basins being known as the Old Reservoir, constructed as

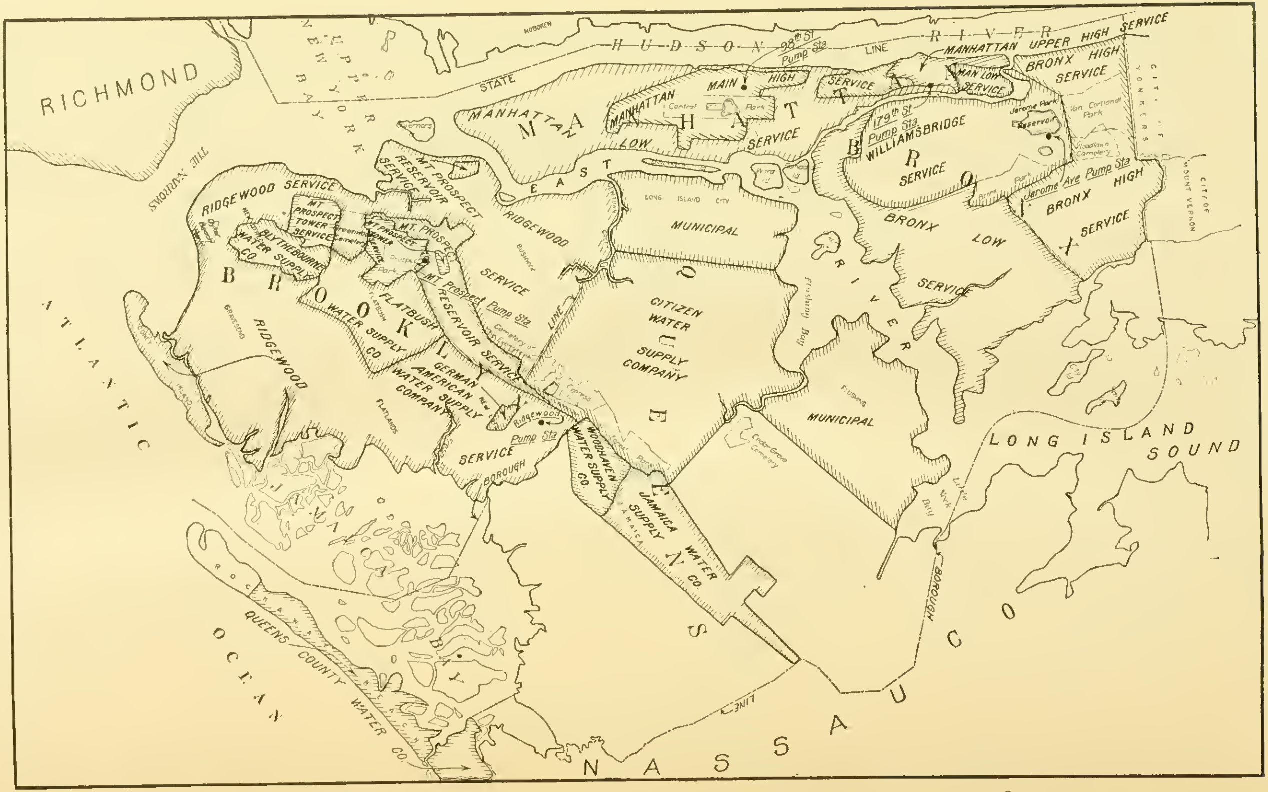


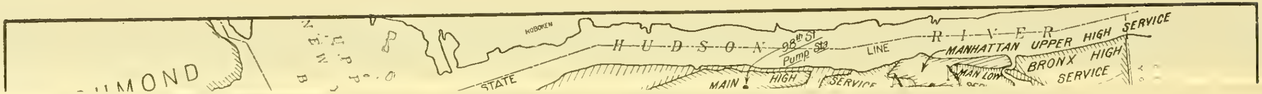
FIG. 3. DISTRIBUTION SERVICE IN MANHATTAN, BROOKLYN, BRONX, AND QUEENS.

TABLE No. 2.

DISTRIBUTION SERVICES. BOROUGHS OF MANHATTAN AND BRONX.

Manhattan.

Designation.	Area Supplied.	Population Served.	Consumption. M. G. D.	Reservoirs and Standpipes. Name.	Location.	Source of Supply.	Elevation of Nominal High Water. Feet.	Depth. Feet.	Capacity. M. G.	Pumping Stations. Name.	Location.	Source of Supply.	Pumpage. M. G. D.
Low service.	Southerly and easterly sections lying mainly below elevation 40.	1 900 000	230	Old Central Park Reservoir.	Between 79th and 86th sts.	Croton River through Old and New Croton aqueducts.	118	20 & 30	211		Gravity supply.		
				New Central Park Reservoir.	Between 86th and 95th sts.			36	1 000				
Main high service.	Central and westerly sections above 34th St.	340 000	60	High Bridge Reservoir.	175th St. and Harlem River.	High Bridge and 179th St. Stations.	225	16	11	High Bridge.	Same as reservoirs and standpipes.	Old Croton Aqueduct.	2
				179th St. Standpipe.	179th St. and Harlem River.	179th St. Station.	225	134	.028	179th St.		New Croton Aqueduct.	40
				98th St. Standpipe.	98th St. west of Columbus Ave.	98th St. Station.	219	170	.036	98th St.		Both aqueducts.	18
Upper high service.	Northerly section.	30 000	7	High Bridge Standpipe.	175th St. and Harlem River.	179th St. Station.	324	243	.056	179th St.	Do.	Do.	7
Bronx.													
Low service.	Easterly section and low ground in southerly section and near Harlem River.	170 000	10	Jerome Park Reservoir, West Basin.	Jerome Ave. between E. 194th St. and E. 210th St.	Old and New Croton aqueducts.	134	27	770		Gravity supply.		
Williamsbridge service.	Central section.	120 000	16	Williamsbridge Reservoir.	E. 208th St. and Woodlawn Road.	Bronx and Bryam rivers.	193	37	140		Gravity supply.		
Bronx high service.	Northerly and westerly sections.	50 000	10	Jerome Ave. Standpipe.	Jerome Ave. and Van Cortlandt Ave.	Jerome Ave. Station.	303	185	.039	Jerome Ave.	Same as standpipe.	Jerome Ave. Reservoir and Old Croton Aqueduct.	10


HUDSON RIVER
MANHATTAN UPPER HIGH SERVICE
BRONX HIGH SERVICE
LINE
98th St Pump Sta
MAIN HIGH SERVICE
HOBOKEN
STATE

part of the original works, and the northerly basin as the New Reservoir, this basin being put in service in 1862. The normal flow-line is at elevation of 118, and the capacity of the three basins is about 1 200 m. g. A distributing reservoir, formerly located on 5th Avenue, between 40 and 42d streets, was removed in about 1901, and a public library building has been erected on this site.

About 75 per cent., or 240 m. g. d., of the Croton supply is distributed from the low level reservoirs, which gives a resulting hydraulic gradient in downtown Manhattan, during the day time, equivalent to elevation of about 70. As a large area of the Bronx and Manhattan boroughs lies above the level which can be supplied from the low level reservoirs, high services have been created by pumping the Croton water. The intermediate high service in Manhattan, which is known as the main high service, requires about 60 m. g. d., which is pumped at stations located at 98th Street, near Columbus Avenue, and 179th Street and the Harlem River, a small station at High Bridge being a reserve station. The 98th Street station pumps about 15 m. g. d. into a tower at the station, with an overflow at elevation of 219, while the 179th Street station pumps about 45 m. g. d. into its tower, with an overflow at 225. A small reservoir located at the westerly end of High Bridge is also used for this service. The upper high service supply of about 7 m. g. d. is pumped at the 179th Street station against the High Bridge standpipe pressure, this standpipe having an overflow at an elevation of about 324, and serves the high ground lying at the northerly end of Manhattan Island, this ground rising to a maximum elevation of 240.

In the borough of The Bronx the low ground is served by the Croton from the Old Aqueduct and Jerome Park Reservoir. The supply from the Bronx and Byram rivers is taken from Lake Kensico, formed by a dam across the Bronx River at Kensico, N. Y., and delivered by a single 48-inch pipe, 15.2 miles long, to the Williamsbridge Reservoir located to the east of the Jerome Park Reservoir. The watershed tributary to Lake Kensico is 22 square miles, and there are four upper lakes available for storage, having, with Lake Kensico, 4 141 m. g. capacity. The supply, which averages about 20 m. g. d., is used for the intermediate service in The Bronx, any surplus flowing into the Croton low service. The

Williamsbridge Reservoir contains 140 m. g., with the water level at elevation of 193.

The high ground, which rises to a maximum elevation of about 280, is supplied by the Bronx high service. The Jerome Avenue station, located just east of the Jerome Park Reservoir, pumps about 10 m. g. d. into a standpipe with an overflow of elevation 303. This supply comes from the Croton low level system.

The distribution system consists of 1 200 miles of mains, varying from 4 to 60 inches in diameter, on which have been set 18 500 gates and 18 400 hydrants. There are about 150 000 services, of which about one third are metered. The average daily consumption of the boroughs of Manhattan and The Bronx is about 330 m. g., and the population, 2 600 000, which gives a per capita use of 127 gallons daily.

The original Croton works cost $12 000 000, and with the additions since that time, including the Bronx and Byram works, have cost about $100 000 000.

In connection with the water supply system, a separate high pressure fire service has been installed to reduce the fire loss and conflagration hazard in the downtown section of the borough of Manhattan. This system at present covers an area of about 1 450 acres, being bounded, approximately, by the Hudson River, 23d Street, Broadway and the Bowery, and Chambers Street. Within this area 50 miles of mains from 12 to 24 inches in diameter have been laid, with 896 gates and 1 274 hydrants. There are about 5 miles of 8-inch pipe laid for hydrant connections and an 8-inch valve on each connection. The mains are supplied by two pumping stations, one located on the East River at Oliver Street opposite, approximately, the southeast corner of the protected district, and the other at Gansevoort Market on the Hudson River, in the northwesterly part of the district. Each station is connected to use either the salt water from the river or the fresh water from the Croton system, it being expected to use the salt water only as an emergency supply. Each station has five Allis-Chalmers 6-stage turbine pumps, driven by electric motor, each pump being capable of delivering 3 000 gallons per minute against a head of 300 pounds per square inch at the station. The ordinary fire engine can pump about 700 gallons per minute

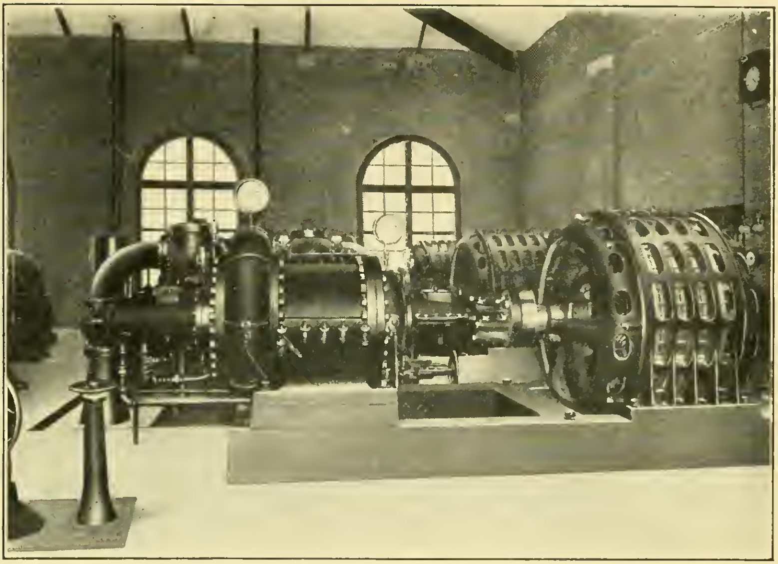


FIG. 1. A PUMPING UNIT. GANSEVOORT HIGH PRESSURE STATION.

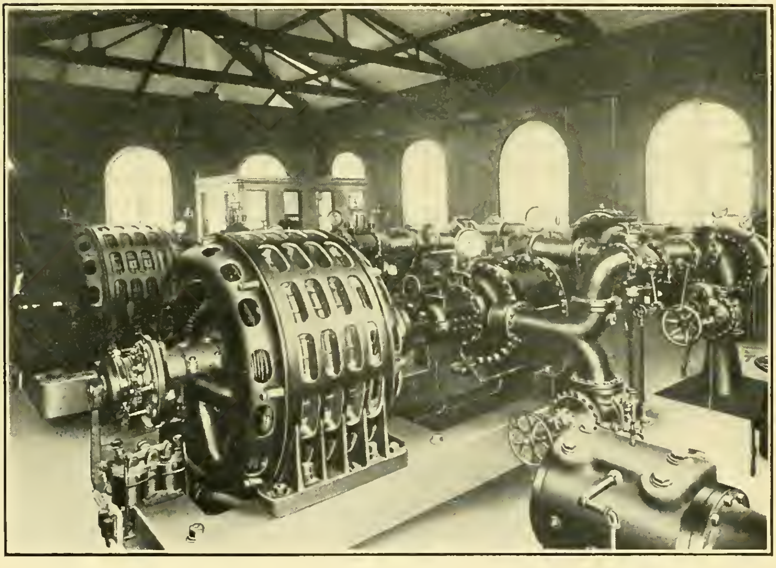


FIG. 2. INTERIOR OF GANSEVOORT HIGH PRESSURE STATION.

Test of High Pressure Fire Service on West Street, near Gansevoort Station.

at a pressure of somewhat less than 200 pounds per square inch, and the combined capacity of the two high-pressure stations is equal, therefore, to more than 40 fire engines, each furnishing two good streams. Each hydrant is equipped with three 3-inch and one 4½-inch outlet, with independent valves, and, by siamesing, approximately 10 lines of hose can be run from each hydrant. The hydrants are of special design manufactured by the A. P. Smith Manufacturing Company. Extensions to this system are now under contract to cover a portion of the East Side bounded by James Street, Bowery, East Houston Street, and the East River, this district being considered a serious conflagration hazard, menacing to other and more valuable portions of the city. The high-pressure system has cost somewhat less than $4 000 000 for stations, land, mains, and appurtenances. The extensions now under way are estimated to cost about $1 500 000.

The construction of reservoirs and other developments in the Croton system is under the Aqueduct Commission, consisting of Mayor George B. McClellan; Comptroller Herman A. Metz, Commissioners J. F. Cowan, president; W. H. Ten Eyck, J. J. Ryan, and J. P. Windolph; Mr. Walter H. Sears being chief engineer. The maintenance and operation of the Croton system, together with all work on distribution, including the high pressure system, is under the Commissioner of Water Supply, Gas and Electricity, Mr. John H. O'Brien, Mr. I. M. de Varona being chief engineer.

BOROUGH OF BROOKLYN.

Brooklyn was dependent upon individual private and public wells and cisterns prior to the introduction of water from the Ridgewood system in 1859. At this time the population was about 250 000, the total area of what was then incorporated as the city of Brooklyn being less than one half of the territory at present included in the borough of Brooklyn. The original works extended about 12 miles to the east of what is now the borough line between Brooklyn and Queens, along the south shore of Long Island, and in 1890 an additional supply was obtained by extending the terminus about 10 miles to the east, thus including practically all the territory on the south side of the island to the west of the

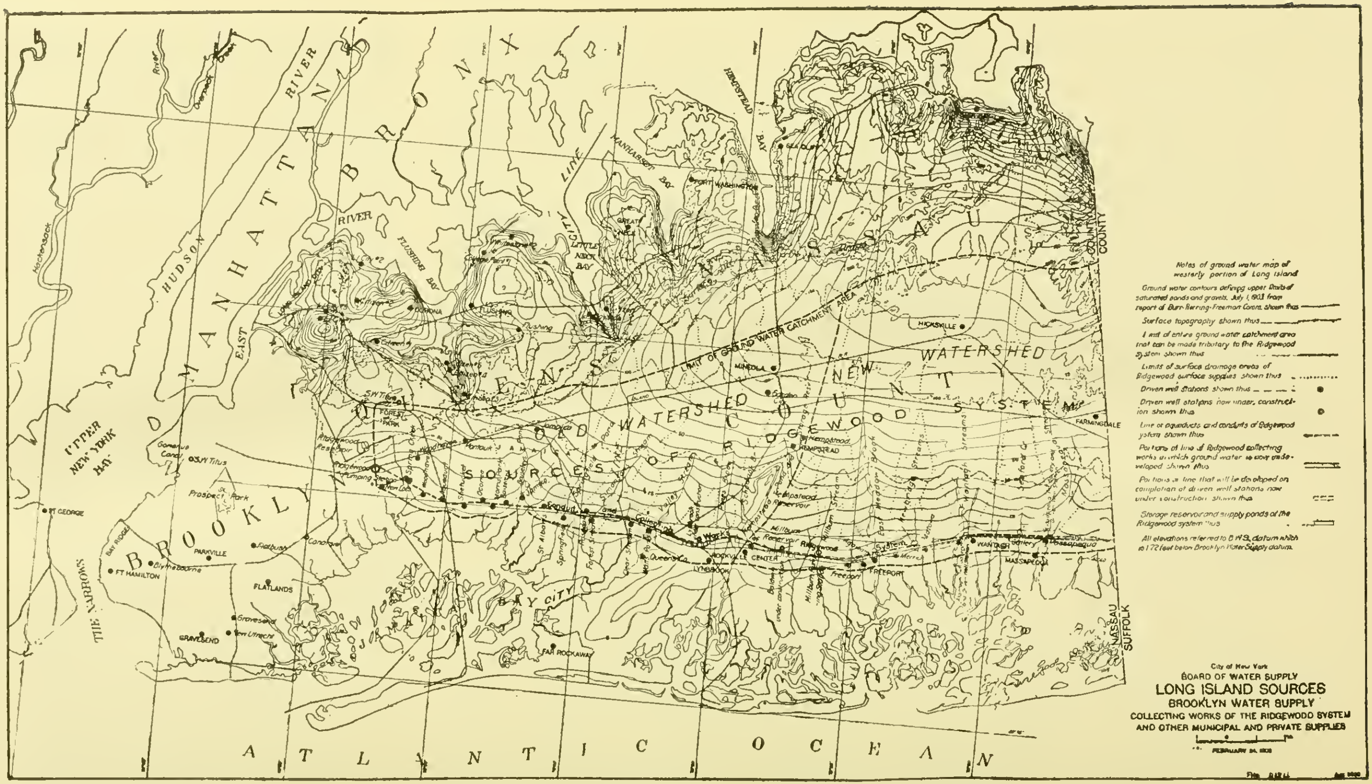


FIG. 4. SOURCES OF SUPPLY FOR BROOKLYN AND QUEENS.

Suffolk County line, the watershed area being about 159 square miles. The watershed consists mainly of a sandy outwash plain several hundred feet in depth, the surface sloping gently upward from the salt water bays northerly to a ridge of hills formed by a glacial terminal moraine, the surface rising rather sharply in the central part of the island to an elevation which is, in general, somewhat less than 200 feet above sea level.

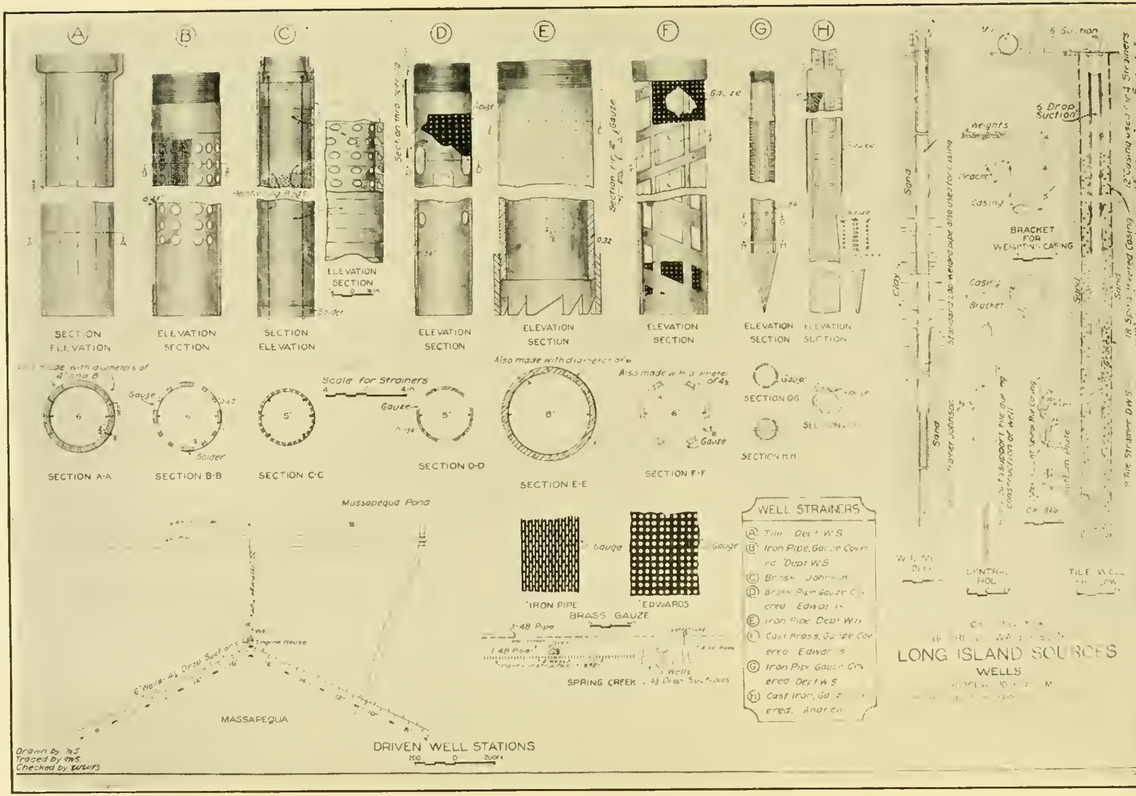
The conditions on this watershed are the exact opposite of those on the Croton shed, where storage of water on the surface is the economical method of obtaining a large percentage of the rainfall. On the Brooklyn watershed the storage of a large quantity of water on the surface is practically impossible, due to the pervious soil and slight changes in ground level, and there is only one supply reservoir that holds over 50 m. g., this being known as the Hempstead Storage Reservoir, built in 1870–1875, just south of the town of Hempstead, and containing about 880 m. g. with a flow line at elevation of 30, this being equivalent to a depth of about 19 feet at the dam, which is of earth with a clay core wall.

The supply from the Brooklyn shed is derived mainly from small streams on which shallow ponds have been formed, and from driven wells and infiltration galleries drawing on the sub-surface waters. This form of development is due to the geological character of the watershed, which, on account of its sand and gravel formation, absorbs nearly all the rainfall, amounting to about 43.5 inches yearly. The rainfall which does not evaporate and is not used for vegetation passes slowly through the upper sands to the saturated bed and then flows slowly toward the sea, this rate of flow being usually less than a mile per year. The saturated water-table is an almost uniform plane, sloping at an average rate of approximately 10 feet per mile toward the sea, this slope being a maximum near tide water and a minimum in the central part the island. Where the land surface dips below the water-table, a small stream is formed, which is fed by both surface run-off and sub-surface flow. It is estimated that each year about 14 inches of rainfall flow through the streams and about 12 inches pass out to the bays and ocean through the sands and gravels. Beds of clay of a thickness varying from a few inches to about 50 feet, and of irregular shape and area, divide the underground flow into several strata.

Taking advantage of the natural stream and reservoir of filtered water that underlie the south side of Long Island, the supply from the surface streams has been supplemented and, to a large extent, supplanted in recent years by the sub-surface development.

The first sub-surface development consisted of an open brick well about 50 feet in diameter, but this was not successful in adding materially to the supply. In 1882 groups of 2-inch wells, located about ½ mile from tide water where the water level was at elevation of 5 to 10 feet, were driven to a depth of about 40 feet and connected to a central suction pipe about 700 feet in length laid at approximately the ground water level. From 100 to 150 of these wells, with strainers 5 to 7 feet in length formed by soldering perforated brass sheets over ribbed-iron frame, were driven for each station, and by lowering the water level from 10 to 15 feet a supply of from 2½ to 5 m. g. d. could be obtained. The well system was later modified by increasing the diameter of the wells to from 4½ to 8 inches, lengthening the strainers to from 10 to 20 feet, and reducing the number of wells. The strainers were made of solid brass, brass frame covered with perforated brass, and iron frames covered with brass. Wells surrounded by gravel were also tried, a casing about 6 inches larger than the well being sunk and refilled for about 3 feet with gravel. The well strainer was lowered until the bottom rested on the gravel, and then gravel was placed around the well and the casing withdrawn. Both metal and vitrified pipe wells were constructed in this manner and gave an increased discharge and lasted longer than the wells without gravel. As a great deal of trouble was occasioned by the clogging of the wells, and the small stations were inefficient and expensive in maintenance and operation, it was decided to construct two infiltration galleries, known as the Wantagh and Massapequa gallery stations. These galleries consist of vitrified tile pipe, laid at right angles to the line of flow and from 10 to 15 feet below the normal water level. The Wantagh station consists of a central station with a brick pump well, 18 feet in diameter, with bottom at elevation of —10. Pipes 36 inches in diameter, with open joints and surrounded by gravel, are laid each way from the well, commencing with invert at elevation —5.0. The pipes gradually reduce to 20 inches at the ends, and grade of invert rises to elevation of —2.0. The

PLATE IV.



WELLS USED IN THE RIDGEWOOD SYSTEM, BROOKLYN.

TABLE No. 3.

SOURCES OF SUPPLY, BOROUGH OF BROOKLYN.

Municipal Works.

Designation.	Source of Supply.	Average Amount Furnished, 1908. M. G. D.	Year First Util-ized.
New Utrecht Station........	Driven wells	1.1	1885
Gravesend Station..........	,, ,,	3.2	1891
Canarsie Station............	,, ,,	Completed in 1909; supply about 3 m. g. d.	1909
New Lots Station..........	,, ,,	6.9	1881
Spring Creek Station........	,, ,,	4.1	1882
Woodhaven Station.........	,, ,,	3.1	1907
Aqueduct Station..........	,, ,,	3.1	1906
Shetucket Station..........	,, ,,	1.9	1897
Oconee Station.............	,, ,,	3.6	1897
Morris Park Station........	,, ,,	2.2	1907
Baiseleys Station...........	,, ,,	0.9	1883
Jameco Station............	Driven wells		1891
	and Baiseleys Pond	10.6	1858
St. Albans Station.	Driven wells	2.0	1905
Springfield Station..........	,, ,,		1897
	and pond	2.6	1881
Rosedale Station...........	,, ,,	2.7	1906
Forest Stream Station......	,, ,,		1885
	and pond	5.2	1860
Clear Stream Station........	,, ,,	3.3	1885
Watts Pond Station........	,, ,,		1894
	and pond	4.2	1881
Valley Stream Pond........	Stream	Included below	1860
Lynbrook Station..........	Driven wells	0.6	1907
Smiths Pond Station.......	Pond	7.9	1872
Pines Pond................	Stream	Including	1860
Shodack Brook.............	,,	Valley	1873
Hempstead Storage Reservoir	,,	Stream	1874
,, Pond............	,,	5.7	1860
Millburn Station...........	Pond	*	1891
East Meadow Pond.........	Stream	*	1891
Agawam Station...........	Driven wells	1.1	1896
Merrick Station............	,, ,,	1.7	1896
Newbridge Pond..........	Stream	*	1891
Matowa Station............	Driven wells	1.3	1896
Wantagh Pond.............	Stream	*	1891
,, Infiltration Gallery Station........	Infiltration gallery	8.2	1905
,, Driven Well Station	Driven wells	0.02	1896
Massapequa Pond..........	Stream	*	1891
,, Driven Well Station..........	Driven wells	0.2	1896
,, Infiltration Gallery Station.....	Infiltration gallery	15.0	1906
*Five ponds (see above)....	Streams	32.2	1891

TABLE No. 3.—*Continued.*

SOURCES OF SUPPLY, BOROUGH OF BROOKLYN.

Private Plants.

Designation.	Source of Supply.	Average Amount Furnished. 1908. M. G. D.	Year First Util-ized.
Titus 6th Street Station	Driven wells	2.8	1908
,, Forest Park Station ...	,, ,,	Under construction	
Flatbush Water Company's Station	,, ,,	10.0	1882
Blythebourne Water Company's Station	Driven wells in bottom of open well	2.0	1891
German American Real Estate Company's Station ...	Driven wells	0.5	1891
Queens County Water Company's Station	,, ,,	3.1	1903

The Titus plants deliver directly into the municipal distribution system, and the Queens County Water Company delivers into the conduit near Valley Stream.

total length of the gallery is slightly over 12 000 feet. The ground water level normally stands at elevation varying from 5 to about 13, and, by lowering the water level in the pump well to about elevation — 6, a supply averaging 12 m. g. d. can be obtained. The galleries, therefore, yield an average of 1 m. g. d. per 1 000 feet of pipe. The cost for construction is approximately $15 per linear foot. The Massapequa station is similar in design to the Wantagh station, the total length of gallery being 18 000 feet.

The supply from the eastern section of the watershed, amounting to from 60 to 70 m. g. d., is drawn from five streams, five driven well stations, and two galleries. This supply is carried, by gravity, through a brick conduit of horseshoe shape, varying from 5 feet 11 inches by 7 feet 4 inches at the east end to 6 feet 11 inches by 9 feet 4 inches at the west end. The water is delivered to an intermediate pumping station, known as the Millburn station, located near one of the supply ponds just east of Baldwin, Long Island. Here the water is raised from elevation 5 to a pressure equivalent to an elevation of about 60 and forced into three 48-inch mains, two of which carry the water to the main

TABLE No. 4.

Distribution Services, Boroughs of Brooklyn.

Municipal.

Designation.	Area Supplied.	Consumption. M. G. D.	Reservoirs and Standpipes. Name.	Location.	Source of Supply.	Elevation of Nominal High Water. Feet.	Depth. Feet.	Capacity. M. G.	Pumping Stations. Name.	Location.	Source of Supply.	Pumpage. M. G. D.
Ridgewood low service.	All the borough except high ground near Eastern Parkway, Prospect Park, Greenwood Cemetery, Sunset Park, Clinton Ave., Heights sections, and territory of private companies.	120	Ridgewood Reservoir (3 basins).	Cypress Hills Ave. near easterly end of borough.	Ridgewood Pumping Station.	170	20	304	Ridgewood, Old and New Stations.	North and south side of Atlantic Ave. near Logan St.	Wells, infiltration galleries and streams on south side of Long Island.	120
									New Lots.	New Lots Road and Fountain Ave.	Wells.	7
									Gravesend.	Ave. S and E. 17th St.	"	3
									New Utrecht.	Neck Road and E. 15th St.	"	2
									Canarsie.	E. 92d St. and Ave. D.	"	3
									Titus, 6th St.	6th St. and 4th Ave.	"	3
Mt. Prospect Reservoir.	Territory between about elevation 70 and elevation 110, in vicinity of Eastern Parkway, Prospect Park, and Clinton Ave. and Heights sections.	15	Mt. Prospect Reservoir.	Near main entrance, Prospect Park.	Ridgewood and Mt. Prospect Pumping Stations.	198	20	19	Ridgewood, Old Station.	See above.	See above.	10
									Mt. Prospect.	Underhill Ave. and Park Place.	Ridgewood low service.	5
Mt. Prospect Tower.	Territory above about elevation 110, in vicinity of Prospect Park, Greenwood Cemetery, and Sunset Park.	7	Mt. Prospect Standpipe.	Adjoins reservoir.	Mt. Prospect Pumping Station.	278	75	0.11	Mt. Prospect.	See above.	" "	7

Private.

Designation.	Area Supplied.	Consumption. M. G. D.	Reservoirs and Standpipes. Name.	Location.	Source of Supply.	Elevation of Nominal High Water. Feet.	Depth. Feet.	Capacity. M. G.	Pumping Stations. Name.	Location.	Source of Supply.	Pumpage. M. G. D.
Flatbush Water Co.	29th Ward.	10	Standpipe.	Franklin and Washington Aves.	Pumping Station.	180	102	0.24	Flatbush Water Co.	Paerdegat Creek, east of Flatbush Ave.	Wells.	10
Blytheborne Water Co	Blytheborne and Borough Park.	2	Four tanks.	11th Ave. and 74th St.	Pumping Station.	140	..	0.10	Blytheborne Water Co.	Same as tanks.	"	2
German-American Real Estate Co.	Small section in east New York.	½	Standpipe.	Pennsylvania Ave. south of New Lots Road.	Pumping Station.	...	..	...	German-American Real Estate Co.	Same as standpipe.	"	0.5

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pumping station located in the northeast section of the borough known as the Ridgewood station. The third 48-inch main is about 8 400 feet in length and then connects to a 36-inch main 7 600 feet long which discharges into the upper end of the brick conduit built as part of the original works. This conduit runs through the westerly part of the watershed and carries the water, by gravity, to the Ridgewood station. Eleven small driven well stations, four combined pond and driven well stations, one pond pumping station, and five ponds, deliver their supply into this conduit. The conduit is of varying dimensions increasing in size from 6 feet 4 inches by 8 feet 2 inches at the east end to 8 feet 8 inches by 10 feet at the west end. A 72-inch steel pipe, $\frac{7}{16}$ to $\frac{5}{8}$ of an inch thick, is now being laid parallel to the existing conduits, so that about 50 m. g. d. can be forced directly into the distribution system from pumping stations on the east end of the watershed. At the Ridgewood station about 120 m. g. d. is pumped from an elevation of about 7 into the low service, which is fed by the Ridgewood distributing reservoir, having three basins with the flow line at elevation 170, and a total capacity of 304 m. g. About 10 m. g. d. is pumped into the Mt. Prospect Reservoir, which has its flow line at elevation 198, and a capacity of 20 m. g. The higher ground, which rises to a maximum street level of about 170 is supplied from the Mt. Prospect Tower, with its overflow at elevation 278, being fed by the Mt. Prospect pumping station located at the corner of Underhill Avenue and Prospect Place, a few blocks from the entrance to Prospect Park. This station obtains its supply from the Ridgewood service mains and pumps about 7 m. g. d. for the Mt. Prospect Reservoir supply and 7 m. g. d. for the tower supply. The tower and reservoir are located just east of the main entrance to Prospect Park.

There are four driven well stations within the borough limits that pump about 15 m. g. d. directly into the city's mains against the Ridgewood pressure.

The distribution system consists of about 870 miles of mains from 4 to 48 inches in diameter, with about 14 000 gates and 13 000 hydrants. There are about 145 000 taps, of which about 14 000 are metered. The total average daily consumption is about 145 m. g. d. for a population of 1 440 000, or 98 gallons per capita.

The total cost of the Brooklyn system has been slightly over $30 000 000.

Three driven well stations, owned by private companies and furnishing about 12 m. g. d., supply a portion of the borough.

There are two high pressure fire service systems in Brooklyn. The main system was installed in 1905–7, and protects a business and manufacturing district along the East River, running from the Erie Basin to the Navy Yard, and extending back approximately one mile from the river front. This area comprises about 1 400 acres. The supply is furnished by two stations, the main station being located on the river front at the foot of Joralemon Street and the reserve station opposite Fort Greene Park at the corner of Willoughby and St. Edward streets. The main station can draw its supply either from the Ridgewood mains or the East River, and the reserve station from the Ridgewood mains. The equipment of the station consists of Worthington motor-driven 6-stage turbine pumps, delivering 3 000 gallons per minute, against a pressure of 300 pounds per square inch. The pressure is controlled by Ross regulating valves, and the stations are usually run with a pressure of about 150 pounds. The main station has five units, or a capacity of 15 000 gallons per minute, and the reserve station, three units, or a capacity of 9 000 gallons per minute. The pumps exceed their rated capacities, especially at pressure below 300 pounds. The total cost of the installation, which, in addition to the stations, includes about 21 miles of 12 to 20-inch mains, 1 000 gates, and 730 hydrants, was about $1 300 000. Extensions are soon to be made to the pipe system at an estimated cost of $750 000.

The Coney Island high pressure system was installed in 1904–5, and protects the amusement section of Coney Island. The pumping station is located on Coney Island Creek, opposite West 12th Street, and can obtain its supply either from the Ridgewood system or from a salt water creek. The equipment of this station consists of three Nash gas engines, connected to Goulds triplex pumps, each unit having a capacity of 1 500 gallons per minute against a pressure of 150 pounds per square inch. The total cost of installation, including about 1.2 miles of 12- to 16-inch mains, with 61 gates and 47 hydrants, was about $100 000. Extensions to the system are now under way, the estimated cost being about $150 000.

The Brooklyn water works system is under Mr. Walter E. Spear, chief engineer.

BOROUGH OF QUEENS.

The borough of Queens obtains its supply from a number of small driven-well stations, these stations having been built, as a rule, to supply the various separate communities which are now consolidated into one borough. There are 6 municipal plants and about 17 private plants owned by 7 companies. These plants are all comparatively small, the total supply for the borough being about 25 m. g. d.

TABLE No. 5.

SOURCES OF SUPPLY, BOROUGHS OF QUEENS AND RICHMOND.

Designation.	Source of Supply.	Average Amount Supplied. M. G. D.
Queens — Municipal.		
Long Island City, No. 1	Wells	0.8
,, ,, ,, ,, 2	,,	0.8
,, ,, ,, ,, 3	,,	0.6
Flushing	,,	1.6
Bayside	,,	1.2
Whitestone	,,	0.4
Queens — Private.		
Citizens' Water Company, eight stations	Wells	12
Jamaica ,, ,, two ,,	,,	3
Queens ,, ,,	,,	2.5
Woodhaven ,, ,,	,,	2
Bowery Bay Imp't Company	,,	0.5
Montauk Water Company	,,	1.5
Woodside ,, ,, three stations	,,	Not in use
Richmond — Municipal.		
Tottenville	Wells	0.3
Three stations for West New Brighton, etc	,,	4
,, ,, ,, Stapleton, etc	,,	3.7
Richmond — Private.		
South Shore Water Supply Company	Wells	0.2

These stations pump directly into the distribution mains and usually have a standpipe connected to the system. The amount delivered is estimated on pump displacement.

BOROUGH OF RICHMOND.

The supply of this borough is obtained from eight driven well stations, of which one plant has been owned by the city for several years, the remaining plants, with exception of a very small system, having been recently acquired by the municipality. The supply obtained from these plants, which amounts to about 8 m. g. d., is inadequate to serve the borough, the population of which is about 80 000. A contract has been made with a private company for an additional supply of from 3 to 10 m. g. d., to be obtained from New Jersey, this contract to run for ten years.

ADDITIONAL SUPPLY.

The safe supply from the systems utilized for all the boroughs, with the possible exception of the borough of Queens, is hardly sufficient to meet the requirements of the consumers during a period of drought of a severity equal to that which has been experienced in the past. This has been the condition for several years, the increase in supply obtained by the construction of new reservoirs on the Croton watershed and the additional development of the underground supply of Long Island, west of Suffolk County, hardly keeping pace with the increase in consumption, and further permanent relief from such development is impracticable.

Upon completion of the Croton Falls Reservoir now under construction, the then available supply and the present consumption may be estimated as follows:

Borough.	Safe Minimum Supply. M. G. D.	Average Daily Consumption. M. G. D.
Manhattan, Bronx	350	330
Brooklyn	150	155
Queens	40	25
Richmond	7	8
Total	547	518

The present margin of safety is so small that it will be used up by the increase in consumption in a year or so. The consumption would probably have been in excess of the safe supply before now had it not been for the abnormally low consumption caused, in part, by the general business depression.

In 1899, alleging that the supply was then inadequate, an attempt was made by certain city officials to enter into a contract with a private company to supply 200 m. g. d. at a cost of $70 per million gallons, this contract to run for a period of forty years. The opposition to this contract resulted in careful investigations of the present and future supply, and two extensive reports, one to the then Comptroller, Bird S. Coler, by Mr. John R. Freeman, dated March 23, 1900, and the other to the Merchants' Association, made in 1900 by its Engineering Committee, of which Mr. Thomas C. Clark was chairman. These reports condemned the proposed contract, and were followed about two years later by an exhaustive examination and report made by the Commission on Additional Water Supply, composed of Messrs. William H. Burr, Rudolph Hering, and John R. Freeman, this report being submitted under date of November 30, 1903.

As a result of the evident and urgent need of an additional supply, and in accordance with the recommendations of Mayor George B. McClellan, the creation of the Board of Water Supply to construct the necessary works was authorized by the legislature in 1905. At the same time the State Water Commission was created, to control the water resources of the state. In June, 1905, the Mayor appointed Messrs. J. Edward Simmons, Charles N. Chadwick, and Charles A. Shaw as the three commissioners to form the Board. Mr. Simmons, who was the president of the Board, resigned in January, 1908, and was succeeded by Mr. John A. Bensel; Mr. J. Waldo Smith was appointed chief engineer; Mr. John R. Freeman, consulting engineer to the Board; and Messrs. William H. Burr and Frederick P. Stearns, consulting engineers to the chief engineer.

A report was made by the Board of Water Supply to the Board of Estimate and Apportionment on October 9, 1905, recommending the development of four watersheds in the Catskill Mountains as the most available sources of supply, with sufficient conduit capacity to deliver 500 m. g. d. to the city, at a total cost of about $162 000 000, exclusive of delivery of the supply for the boroughs of Manhattan and the Bronx, the cost including works to deliver 100 m. g. d. to Queens and Brooklyn and a connection to Richmond. It was considered that the expenditure of $112 000 000

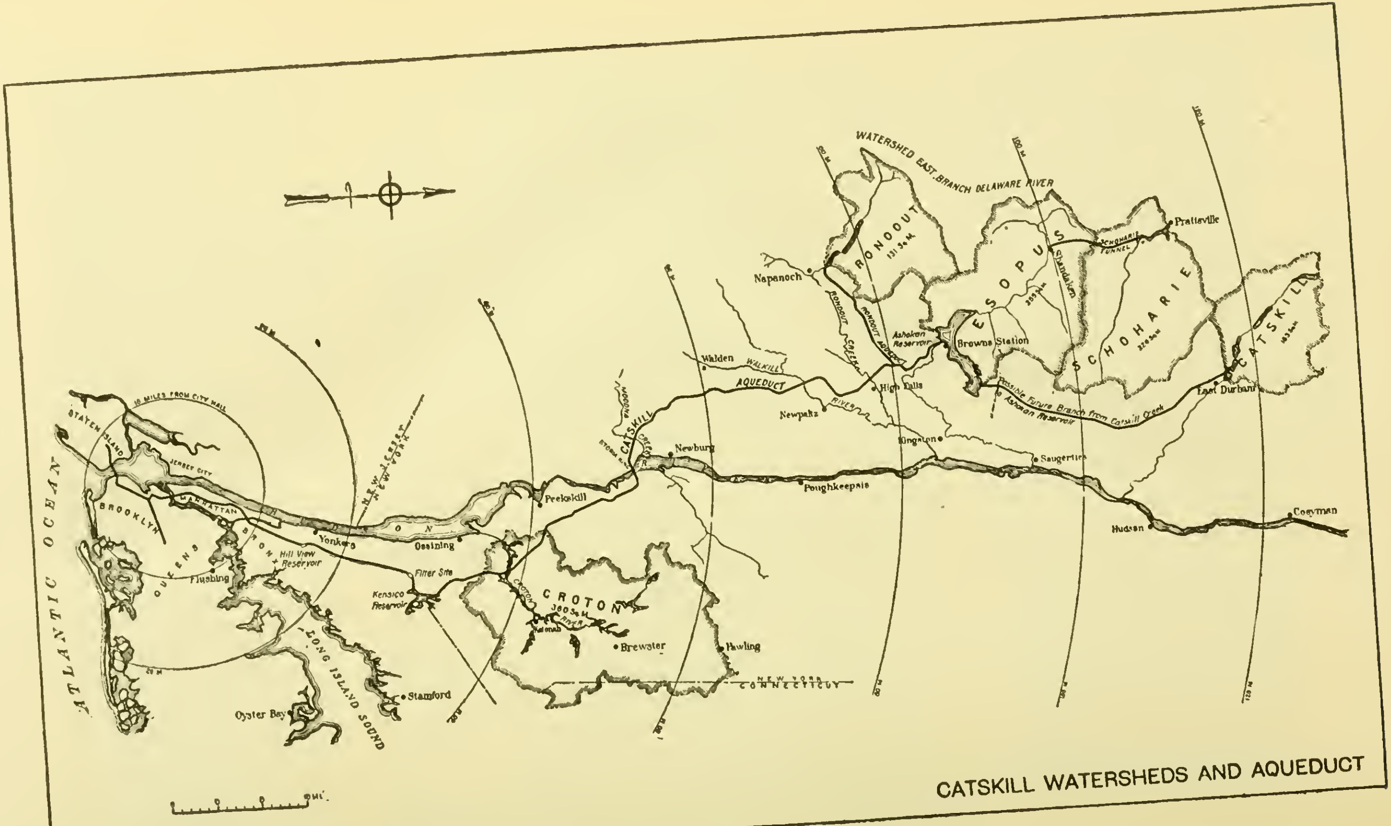


Fig. 5. Outline of the Catskill System.

Fig. 1. Boring Rig in Esopus Creek at the Olive Bridge Dam Site.

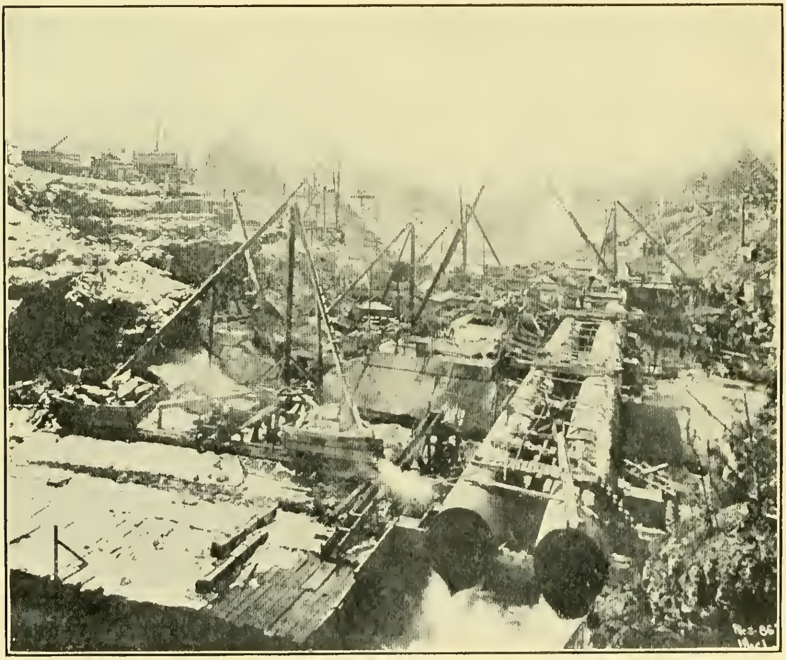


Fig. 2. Olive Bridge Dam, looking Up Stream.
Showing dam under construction and two 8 ft. steel pipes used for river control.

would be sufficient to develop a supply of 250 m. g. d., the additional 250 m. g. d. being developed later, as required. Recommendation was made that the Long Island watersheds be studied, with a view to their development as the most available source of supply for the immediate needs of Brooklyn, Queens, and Richmond boroughs. The plan proposed was approved by the State Water Commission and work is now actively in progress, the expenditures to date, together with estimated cost of work under contract, amounting to over $50 000 000.

The watersheds adopted for the supply consist of Esopus, Rondout, Schoharie, and Catskill creeks. The waters of the Schoharie Creek are to be delivered by tunnel into the valley of the Esopus Creek, branch aqueducts being planned to convey the Rondout and Catskill creek waters to the main aqueduct. An enormous reservoir, known as the Ashokan Reservoir, is to be developed in the Esopus valley. From this reservoir an aqueduct to deliver 500 m. g. d. is to be built, consisting of cut-and-cover, grade tunnel, pressure tunnel, and pipe siphon sections. A large receiving and storage reservoir is to be constructed on the east side of the Hudson River on the site of the existing Lake Kensico. An equalizing reservoir is to be constructed on the high ground just north of Van Cortlandt Park, the water being carried from this reservoir in pressure tunnel to the boroughs of The Bronx, Manhattan, and probably Brooklyn, and by pipe lines to the boroughs of Queens and Richmond.

The Ashokan Reservoir will receive the drainage of about 257 square miles of watershed on the Esopus Creek and about 228 square miles on the Schoharie Creek. Its flow line is to be at elevation of 590 feet. The reservoir is to be divided into two basins, having a total capacity of 128 000 m. g., flooding an area of about 12.8 square miles, and having a shore line of about 40 miles. The main dam is to be a masonry structure across the Esopus Creek, 1 000 feet long at the top and having a maximum height of 240 feet. Additional dams and dikes will have to be constructed of a total length of over 5 miles. The aqueduct is to be of concrete of varying dimensions, depending upon whether it is of cut-and-cover, grade tunnel, or pressure tunnel type. The hydraulic gradient at Ashokan Reservoir is to be at elevation of 510,

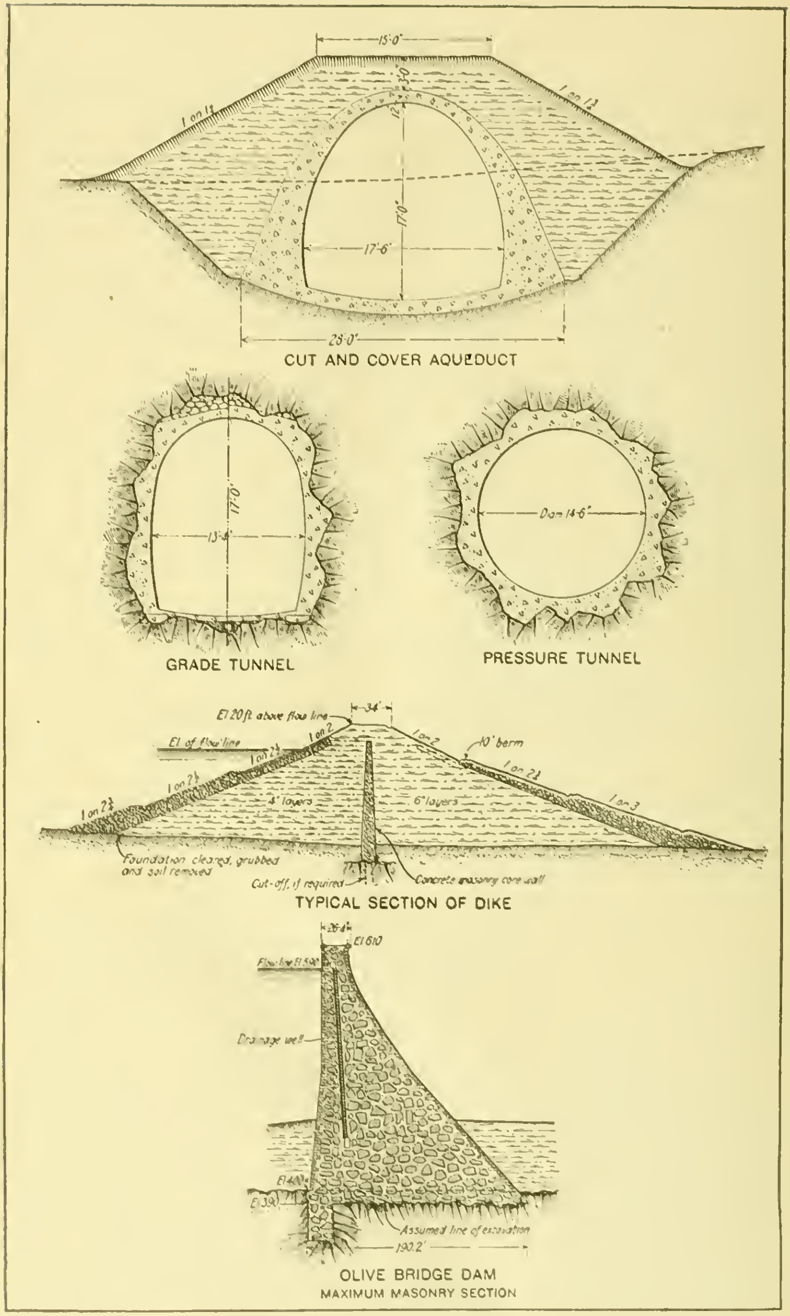
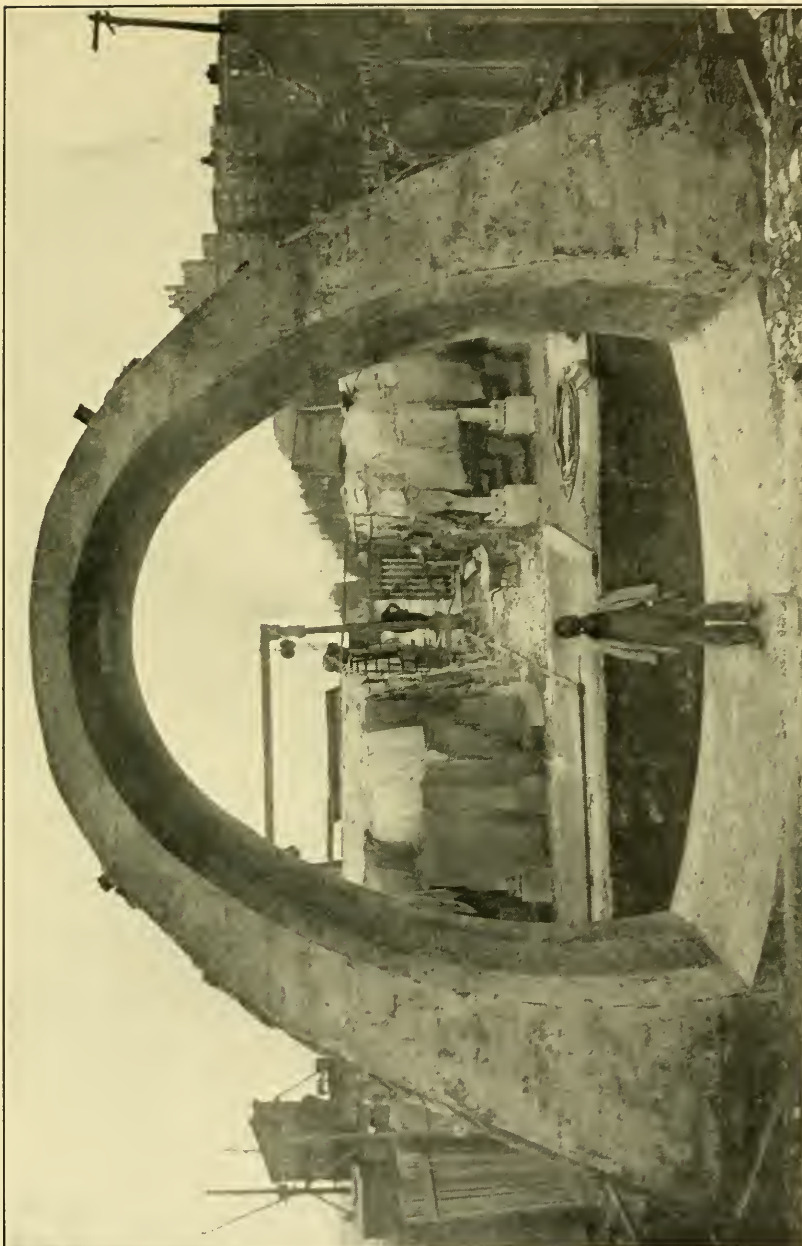


FIG. 6. SECTIONS OF THE CATSKILL AQUEDUCT, TYPICAL DIKE AND OLIVE BRIDGE DAM.



CATSKILL AQUEDUCT — Full-Size Concrete Model of Aqueduct as it will be built in Trench. Test section.

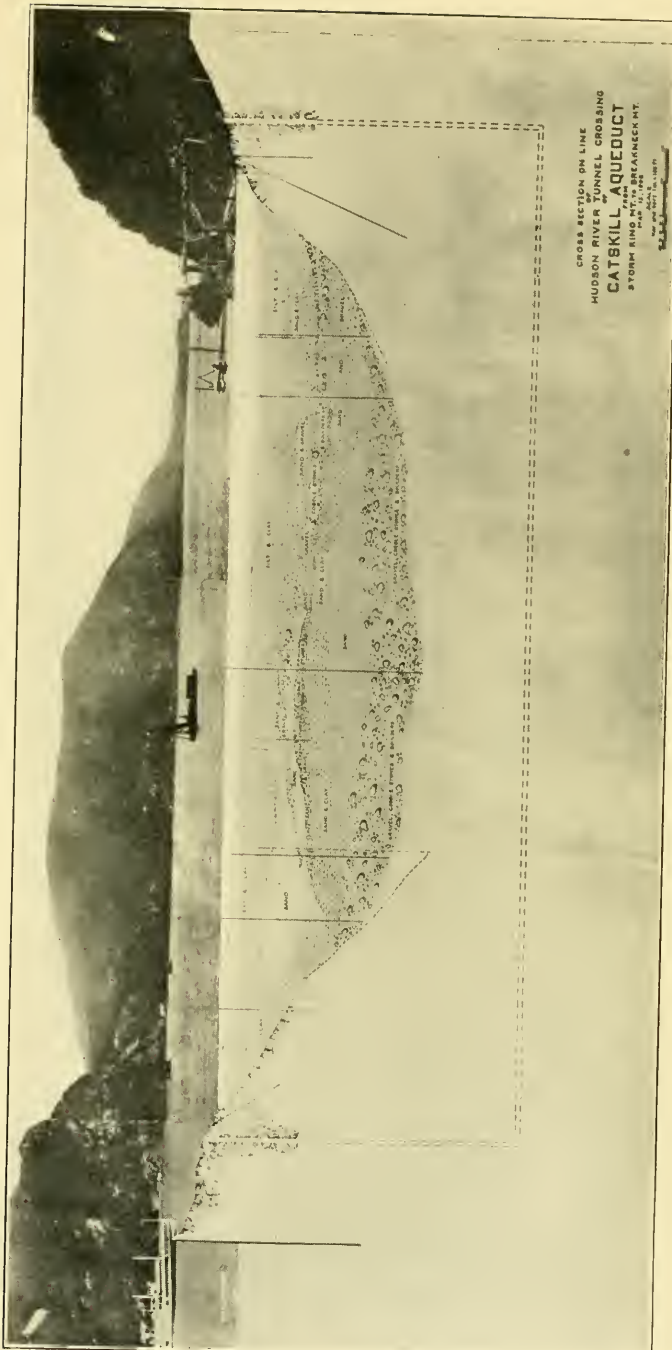
which will reduce to 355 at Kensico Reservoir, the gradient varying for the different types of aqueduct, being a maximum for the pressure tunnel sections and a minimum for the cut-and-cover section. At Kensico Reservoir there will be a drop of from 25 to 35 feet, and then a fairly uniform gradient to Hill View Reservoir, with its flow line at 295. The total length from Ashokan to Hill View is 91 miles, of which 54.2 miles is to be cut-and-cover type; 13.4 miles, grade tunnel; 17.2 miles, pressure tunnel; and 6.3 miles, steel siphon. From Hill View to Brooklyn the tunnel will be over 16 miles, with 11 miles of pipe to reach Richmond. The cut-and-cover section, which is the largest in area and the lowest in cost per foot, is 17 feet high, with a maximum width of 17 feet 6 inches. The grade tunnels are usually 17 feet high by 13 feet 4 inches wide. The pressure tunnels are circular and vary from 14 feet to 16 feet 6 inches in diameter. The pipe siphons for crossing valleys where the geological conditions are unfavorable for pressure tunnels are to be of steel covered with concrete and lined with cement mortar, the clear inside diameter being from 9½ to 11 feet. The lowest level to which the pressure tunnels have to be driven will be at the Storm King crossing of the Hudson River, where it is expected to go about 1 200 feet below the water level to obtain satisfactory rock for the tunnel. These pressure tunnels, both in size and pressure to which they will be subjected, far exceed any previous tunnels constructed for water works and constitute one of the prominent features in the design of the works.

The Kensico Reservoir is to have a capacity of about 40 000 m. g., with a water surface 355 feet above tide. It is designed as a storage reservoir to be used when the aqueduct north of the reservoir is cut out of service for examination or repairs. The dam for this reservoir is to be of masonry, about 1 830 feet long and nearly 300 feet from the crest to the deepest part of the foundation.

The Catskill aqueduct will deliver its water into the Hill View Reservoir, which will be used as an equalizing basin and will hold approximately 900 m. g. The flow line is to be 295 feet above tide, the depth to be 36.5 feet, and the water surface about 3 000 feet by 1 500 feet. A central wall in which is constucted a bypass aqueduct will divide the reservoir into two basins. South of the reservoir it is expected to construct a pressure

tunnel under the borough of The Bronx, crossing the Harlem River just below High Bridge, running through the borough of Manhattan, and crossing into Brooklyn under the East River just below the Navy Yard. This tunnel is to be of sufficient size to carry the supply delivered by the Catskill aqueduct, and borings are now being made to determine the character and elevation of rock that is to be penetrated. The use of a pressure tunnel for distributing water for a large city is rather unusual, although the Croton pressure tunnel is a precedent in the city of New York. Connections at the various shaft sites to the pipe system are to be provided for the delivery of the Catskill water into any part of the boroughs of Manhattan and The Bronx. For Brooklyn and Queens, large pipes will be required, as the conditions are not favorable for economical extension of the tunnel system. For the borough of Richmond, submerged pipe lines are to be laid across the Narrows, and a reservoir constructed to equalize the pressure and safeguard the supply for this borough. Upon completion of the Catskill works, the city of New York will, with its present sources, have a water supply of over 1 000 m. g. d., of excellent quality, the quantity far exceeding that used by any other municipality in the world.

The Board has carried on extensive preliminary surveys and investigations to determine the available supply from the undeveloped watersheds of Long Island, and last year recommended that the south and easterly sections of Suffolk County be utilized for Brooklyn, Queens, and Richmond by drawing from the subsurface flow. The conclusions of the Board as to the watershed to be developed agree practically with those reached by Mr. I. M. de Varona, at present chief engineer of the Department of Water Supply, Gas, and Electricity, borough of Manhattan, in a report on the additional water supply for Brooklyn, submitted in 1895, although the methods to be followed are different. The Board of Estimate and Apportionment approved, in 1908, the utilization of this source of supply, and the State Water Commission was requested to authorize its development for New York City. Opposition was encountered from owners of large estates within the watershed, and the State Commission has not yet given its approval.



Storm King Crossing for Catskill Aqueduct.

The Catskill works, which are second only to the Panama Canal in magnitude, are being carried on, as has previously been stated, under the direction of Mr. J. Waldo Smith, chief engineer, with Mr. Charles L. Harrison, deputy chief engineer. The work has been divided into four engineering departments, i. e.: Headquarters, Mr. Alfred D. Flinn, department engineer; Reservoir, Mr. Carleton E. Davis, department engineer; Northern Aqueduct, Mr. Robert Ridgway, department engineer; and Southern Aqueduct, Mr. Merritt H. Smith, department engineer. Under these engineers, a corps of nearly 1 000 men are engaged on the surveys, design, and construction of these works, to build which will require the employment of probably 15 000 men, and an expenditure for a time of $2 000 000 per month. While these figures seem stupendous, they give a fair idea of the magnitude of the work that New York City has undertaken to insure an ample supply of water for the next generation.

In preparing this description of New York City Water Works the writer has drawn freely from published reports and papers, it being impossible to acknowledge his indebtedness to the individual authors. He wishes to acknowledge the assistance given by the Board of Water Supply in furnishing lantern slides, maps, and data; to Mr. I. M. de Varona, chief engineer, and Mr. H. B. Machen, assistant engineer, Department of Water Supply, Gas, and Electricity, for slides; and Mr. Arthur S. Tuttle, engineer of public improvements, Board of Estimate and Apportionment, for slides, without whose assistance it would have been impracticable to give the illustrations of both the present and new water works systems.

DISCUSSION.

Mr. William Dart. Will Mr. Brush please tell us something about how the dikes are constructed, particularly as to whether any artificial method of excavation, such as pumping, is used. When work is carried on at such a rapid rate, it is very difficult to obtain the proper solidity, and we often hear of accidents due to that cause. I should like also to ask Mr. Brush whether the dams are kept at a restricted height, so that, say, not more than one foot is raised at a time, and, if the method of pumping is used, what time is allowed for proper solidification of the earthwork.

Mr. Brush. Those are questions which I think can be better answered by some of the other engineers, for I am not connected with that part of the work, and am, therefore, not familiar with the details of construction. Probably Mr. Flinn, our department engineer, can give the gentleman the information desired.

Mr. Alfred D. Flinn. In answer to Mr. Dart's question, I will say that the material available for making the dikes at the Ashokan River Reservoir is particularly suitable for the purpose, being a clay which compacts very solidly. The banks are being built up in layers of varying thickness. On the water side the layers after compacting are about four inches thick, and on the other side about six inches thick. Each layer is spread and rolled, and there is no deposit of earth by any pumping method. It is all done by bringing the earth on to the bank in cars or wagons, spreading it and rolling it, and the banks are kept approximately level in any particular section.

Mr. Edward W. Bemis.* I wish Mr. Brush would explain a little more as to what he meant by legislative restrictions preventing the development of a supply east of the Hudson River.

Mr. Brush. The legislature passed one or more acts prohibiting the use of those watersheds which lie just north of the city and east of the Hudson. Those sources were considered and reported upon favorably by the Additional Water Supply Commission, but subsequently to that report the legislature passed acts prohibiting the utilization of those watersheds for a public water supply for New York City on account of the opposition, as I understand, from the inhabitants of that section, and also from those who are using the water power, against New York City taking those sources for a supply. It would have been cheaper to have used this supply, but these acts prevent it.

Dr. John C. Otis.† I might say, in addition to what Mr. Brush has said, that there are several manufacturing interests, of not very large capacity, along the course of those streams in Dutchess County, and it was thought that their business might be ruined if the water was taken. The great majority of the people of the county were very much opposed to any legislation restricting New

* Superintendent Water Works, Cleveland, Ohio.

† Poughkeepsie, N. Y.

York from taking those watersheds, but the manufacturers had influence enough in the legislature to secure the passage of the acts. We consider that it was a very unfortunate thing for Dutchess County as well as for New York.

Mr. Michael F. Collins.* In Mr. Brush's paper the statement is made that the fire service in New York is connected both with salt water and with the city supply water. Will Mr. Brush please tell us what objection there is to using salt water entirely?

Mr. Brush. The use of salt water is detrimental to the valves, and also, to some extent, to the pipe, and I understand that a greater amount of damage would be caused to merchandise by salt water than by fresh water where a fire does not entirely destroy a building. The amount of water required for fire purposes for the entire city for a year is only about one fifth of a day's supply, and, therefore, is negligible in quantity, and as the use of salt water would probably cause a rather rapid corrosion in the valves, where there is bronze in contact with iron, and also a much less rapid, but still a somewhat rapid, deterioration of the iron pipes, it was considered advisable to use fresh water, and only have the salt water for an emergency supply. The valves and hydrants were designed to use salt water if necessary, and to minimize the corrosion that might be experienced by the use of salt water, but in view of the fact that fresh water was available and such a small amount relatively would be used, it was considered advisable to use fresh instead of salt water.

Mr. Bemis. What effect does it have on the pressure supply mains when you take so much water for a fire, and what size mains do you tap?

Mr. Brush. In Brooklyn the main station obtains its supply from two 48-inch and one 30-inch mains, the water passing to the station through 24-inch and larger connecting mains, the connections at the station consisting of two 24-inch branches. For the reserve station, a 48-inch and a 30-inch main are connected to the station suction main through two 20-inch branches.

In the borough of Manhattan, the Oliver Street station obtains its supply from three 36-inch and one 30-inch mains, having two 30-inch connections to the station. The Gansevoort station ob-

* Superintendent of Water Works, Lawrence, Mass.

tains its supply from one 48-inch, three 36-inch, and one 24-inch mains, with one 30-inch and one 36-inch connection to the station. In each case there is a loop system of supply so that two or more distribution mains are connected to the station, and also a loop delivery system, so that an accident to any part of the system would only cut out a very small section. As far as I know there has never been any appreciable effect by the draft on the mains from the high-pressure stations, its being found that, with from three to four pumps running, the drop at the station is about six pounds. Normally, one pump is more than ample for a fire, and Manhattan has had three large fires at one time during the past season which were controlled by the high-pressure system without any difficulty, and it was not necessary to put into service but three or four of the pumps. If the ten pumps were running, they would require 30 000 gallons a minute, or about 42 000 000 gallons a day, and such a draft would undoubtedly reduce by several pounds the pressure in down-town Manhattan.

GROUND WATERS AS SOURCES OF PUBLIC WATER SUPPLIES.

BY WILLIAM S. JOHNSON, CONSULTING ENGINEER, BOSTON, MASS.

[*Read November 10, 1909.*]

When the average man deals with the unseen, he apparently believes that he is dealing with the supernatural and that the ordinary laws of nature do not apply, or perhaps he goes to the other extreme and builds up an elaborate theory of which he would be ashamed were he dealing with the seen. Such has certainly been the case in dealing with ground waters. Many a man of good sound common sense, who would look with scorn upon any attempt to show that water on the surface of the ground could exercise any attraction for the witch-hazel stick, has without question accepted the theory that water a few feet beneath the surface of the ground, because out of sight, has a power which is not possessed by the same water when it appears on the surface.

On the other hand, many pages of intricate formulas have been published by accomplished scientists treating of the movement of ground waters through soils, when one glance at some deep cut in a sandy soil, such as we have in New England, showing the innumerable strata of every conceivable kind of soil from clay to coarse gravel, with their varying thicknesses and directions, should be sufficient to show that in order to determine the behavior of water beneath the ground it would be necessary to first make an examination of every cubic foot of soil and a new formula for almost every inch. In fact, those of us who have had occasion to study the flow of water through carefully selected material in a sand filter know the absolute impossibility, or rather, the impracticability, of foretelling the result.

Many of you are familiar with the testimony of the eminent geologist a few years ago to the effect that the ground water supplies in eastern and southeastern Massachusetts were obtained from an underground river flowing from New Hampshire toward

the south, and that he had determined the course of this subterranean stream, which was somewhat circuitous, by means of the various public water supplies which had been obtained from the ground. The same geologist explained another water supply in Massachusetts as coming from a subterranean reservoir of water which had been left there in some prehistoric time.

There is no doubt that a theoretical study of the flow of water through soils has produced good results, and that a thorough knowledge of geology is essential to the engineer seeking for ground water supplies. Neither is there any doubt that the witch-hazel has produced good results. In the hands of the intelligent person it has located many excellent wells. It is necessary, however, to state in the beginning that the author is not going to reveal the secret of the witch-hazel, nor is he going to produce a new formula by which a ground water source can be found and its yield computed. The more the writer had seen of ground water supplies, and the more carefully he has studied them, the less confidence he has in his ability, or in the ability of any other person, to foretell what may be found in exploring a new field. With our present state of knowledge of things beneath the earth, experience is certainly the best guide, and experience has taught us many things with relation to ground water supplies, some of which are unknown to those who have not dealt very much with such sources. The object of the present paper is to bring out a few of these points.

Since the expert with the witch-hazel has to some extent been discredited, the expert well driver has taken his place to work upon the same weaknesses in human nature, the same willingness to believe that natural laws do not apply to things unseen, as did his predecessor. There are honest and intelligent well drivers, more now than a few years ago, but the temptation is so great, when business is poor and the mark is so easy, that many a well driver has fallen, and the results are to be found all over the country, where wells have been driven in solid rock, generally at the summit of some hill. There are certainly honest well drivers, for only recently a client who insisted, against the writer's advice, in drilling a well in solid ledge at the summit of a hill confessed that one of the well drivers whom he had consulted had also advised against

it, telling him that at least three out of four wells of this kind were failures. He found, however, two other well drivers who approved most heartily of his plan and were certain that an abundant supply of excellent water could be found by drilling deep enough, at five dollars per foot.

What is said in this paper applies to conditions existing in New England, and may or may not be applicable to other parts of the country; for it is, of course, a fact that the ground waters depend very largely upon the geological conditions, and what is applicable to New England is not necessarily applicable to other parts of the country.

Ground water supplies may be divided into those obtained from deep wells, or the so-called artesian wells, and those obtained from shallow wells, either driven or dug, or from filter galleries located near some surface source.

Concerning deep wells, or the so-called artesian wells, which are generally driven in rock, there is very little to say. They have been tried many times for public water supplies, but have very seldom been successful, but here again it is necessary to call attention to the fact that the author is speaking of conditions in this vicinity only, for there are sections of the country where the deep wells have certainly been very successful. The rock formation in this vicinity is of such a character that it is practically impossible to find a large quantity of water in it unless in some fissure of such a nature that the water passes directly through it from the surface of the ledge. Where a large volume of water has been found in this way, it has generally been of poor quality, but the most common failure is due to the small quantity obtainable.

It is a common belief that water obtained from the rock many feet beneath the surface must be of the greatest purity, but here again we expect something to happen beneath the surface which would not be possible above the surface, for nobody would maintain that the quality of water after passing through concrete, a channel of artificial rock, would differ greatly from the quality of the water entering this channel, and such is practically the condition when water enters a crevice in our granite or other hard rock. There are numerous examples of wells in rock which supply water for manufacturing purposes, and for these purposes they are fre-

quently satisfactory, but the writer knows of no case in Massachusetts at least where the deep well has been a success for a public supply, except, perhaps, where it has been used to secure a small additional supply to supplement some other source, and in each of these cases the water obtained from the deep wells has been of inferior quality. The most satisfactory water supplies are those which are obtained from shallow wells, either dug or driven, or from filter galleries, the water from which is obtained in every case either from the ground in the immediate vicinity or from some nearby surface source.

Water supplies a century ago were almost universally obtained from the ground, and still in the more sparsely settled districts the water supplies are obtained largely from wells. When the knowledge came that water might be the cause of typhoid fever, and the evidence seemed to be good that some serious epidemics had been caused by the water from wells, all wells came to be looked upon with disfavor, and many of them were closed by boards of health and other sanitary authorities, and public water supplies from surface sources were put in to take their places.

It was believed that the ground in the vicinity of dwellings was always saturated with filth which had been thrown upon or discharged into the ground for years, and that any water taken from the ground was unsafe. A great amount was written about the danger lurking in the well, the articles being generally illustrated by the familiar pictures showing by means of arrows the direct course taken by the filth from the cesspool or stable toward the well.

Now the pendulum has swung again, and again the discarded well is in favor, for we now believe that, when properly located, the well furnishes the best, or at least the safest, water, — far safer than the water of the mountain brook.

In 1879, of the 64 Massachusetts cities and towns supplied with water from public sources, 8, or 12 per cent., were supplied from ground water sources. In 1889 the percentage of cities and towns supplied from ground water sources was 31. In 1899 the percentage had reached 38, and now 41 per cent. of the cities and towns supplied with water obtain it from ground water sources.

Much of the increase in the use of ground waters in Massachu-

setts is due to the influence of the State Board of Health. In many cases the State Board of Health has advised against the use of some proposed surface water source and has urged that investigations be made with a view to securing a ground water supply. In some of these cases the ground water supply has been obtained at a considerable saving in expense, and in every case where the investigations have proved successful, water of a superior quality has been secured.

The chief reasons why ground water supplies are more satisfactory than surface sources for public water supply purposes are: *First,* their low temperature in summer; *second,* their attractive appearance and freedom from color, taste and odor; and *third,* the greater safety in their use.

The temperature of water obtained from the ground at the depth from which the supplies are ordinarily obtained is from 48 degrees to 52 degrees unless the water is affected to a considerable extent by the infiltration of surface water from some nearby surface water source, and this temperature is maintained throughout the year. Since ground waters must generally be kept from exposure to the sunlight on account of the growths of organisms which otherwise are likely to occur, the water is not stored in large, open reservoirs where it would become heated, and so is delivered to the consumers at a temperature which does not rise above 60 degrees, even during the warmest days in summer, and is never warm enough to be unpalatable. Surface waters, on the other hand, are frequently delivered to the consumers at a temperature of about 80 degrees.

A good ground water is always clear, practically colorless, odorless, and tasteless, while almost all surface waters are colored and are subject at times to disagreeable odors and tastes. The waters taken from mountain streams without being stored are the best of the surface waters in regard to color and odor, but these are very likely to be turbid at times of storms or of melting snow.

In the report of the Massachusetts State Board of Health for the year 1904 there is an interesting classification of the water supplies according to their different characteristics. In the classification of the surface waters according to their odors there are 32 in a total of 134 surface water sources which are classed as odorless,

or having occasional faint odors. Of these 32 sources which are nearly odorless, 20 are mountain streams, which in many cases are practically spring waters collected in a stream not far below the point at which the water issues from the ground, and should hardly be classed as surface waters.

In the classification according to color it is shown that of 141 sources classified, 22 have color less than 0.05, which may be considered practically colorless. Of these 22, several are ponds like Long Pond in Falmouth, Little South Pond in Plymouth, and Lake Pleasant in Montague, which are practically large open wells, being fed almost entirely from the ground.

It must be admitted that many ground waters have color, and some of them a very high color, but these are not normal ground waters, being affected in each case either by iron or by infiltration from some surface source.

The most important respect in which ground water is superior to surface water is in the comparative safety which attends its use. If the ground water source is properly located, even if the water has at some time been polluted, the danger in its use is reduced to a minimum. The purification effected in passing through soil at a rate as slow as water passes laterally through the ground is, we know now, very great, and it is almost impossible for disease germs to survive except under extraordinary conditions.

With the mountain streams, on the other hand, from which the most attractive surface waters are obtained, even if their watersheds are uninhabited, there is constant danger of pollution by the hunter, the fisherman, or in innumerable other ways. Any pollution entering such a stream is carried quickly and directly into the piping system and delivered to the consumers with no opportunity for the purifying effects of time or storage.

In case of ponds or storage reservoirs with uninhabited watersheds, the danger from pollution is less serious than in the case of streams, but there is always more or less danger, even with the most careful supervision of the source and its watershed. In addition to this there is the certainty of the fouling of the water by animals of various kinds, alive and dead, which, while perhaps not having a serious effect upon the health of those using the water, certainly makes the water less appetizing.

When we come to think of it, we must realize the absolute impossibility of securing water from the surface of the ground which shall be perfectly clean. There must be within the watershed of every surface source quantities of decaying organic matter from the leaves and other vegetation, as well as from animals, which will be washed into the water during every shower. In case of the pond or reservoir, purification by storage takes place, and the effect of this dirt is much less than in the case of the running stream, where there is little opportunity for the water to free itself from the impurities. Water taken from sand or gravel beneath the surface of the ground is generally absolutely free from any of this dirt.

The time is undoubtedly coming, and is not far distant, when all surface water supplies will be filtered before they are used for domestic purposes. The public is rapidly becoming educated in these matters, and it will soon be insufficient to know that the use of a water is not likely to give typhoid fever, and there will be a demand that the water shall be free from the filth which all surface waters contain in a greater or less degree.

The objectionable or troublesome features of ground waters are: *First*, the uncertainty which must exist as to the quantity of water available; *second*, the conditions which favor the growth of organisms in the water; *third*, the possibility of the presence of iron; and, *fourth*, the possible deterioration of the water with long-continued use.

The uncertainty as to the quantity of water is one which can be met only by making thorough tests. In the case of a surface water source it is possible to foretell with considerable accuracy the amount of water which the source will yield in a very dry season. In the case of a ground water supply it is impossible, even with as thorough a knowledge of the soil as it is feasible to obtain, to foretell the quantity of water obtainable.

In recent years it has been the custom in the most important investigations of ground water sources to make a pumping test to assist in determining both the probable quantity and the probable quality of the water to be obtained. The method of making these pumping tests will be referred to later. With the information furnished by the pumping test, especially if the test is con-

ducted during a period when the ground waters are at a low level, it is possible to make a sufficiently close approximation of the quantity of water available.

Ground waters, when exposed to light for a considerable time, are almost certain to contain growths of organisms, which, when they decay, will cause the water to be very objectionable. When the first ground water supplies were introduced, this fact was not known, and the water in many cases was stored in large open reservoirs. During the summer months the water in these reservoirs was affected by growths of organisms to such an extent that the water could hardly be used for domestic purposes. Such was the case in Newton, Brookline, Hyde Park, and several other of the Massachusetts cities and towns, and in all of these places it became necessary to provide covered reservoirs so that the water is not exposed to the light from the time it leaves the ground until it reaches the consumer. This not only prevents the growth of organisms, but it also perserves the low temperature of the water, which was not possible with the open reservoirs where the water was exposed to the sun.

Most of the troubles which have occurred with ground water supplies have been due to the presence of iron in the water. Iron occurs in ground waters in various forms, but in whatever form it occurs, the final result is the same. It causes rust spots on clothes which are washed in it, imparts to the water a color and an objectionable odor and taste, fills up service pipes, and clogs up the wells. In fact, there is nothing which causes so much complaint or trouble with a water supply as the presence of iron. It is not necessary at the present time to discuss the chemistry of the presence of iron in the water, but, in general, it may be said that the iron is the result of imperfect filtration of water containing organic matter.

It may be that the imperfectly purified water comes from some nearby surface source, or the water may have come through a deposit of peat from which it takes up organic matter, but in either case the presence of iron indicates that the water has not been completely purified in its passage to the well. Water obtained from a well sunk in a swamp where there is an extensive deposit of peat, with no impervious layer between it and the water-bearing

stratum, is almost invariably affected by iron. Water obtained from a well located close to a stream is likely to be affected by iron after long-continued draft from the well at a rate considerably greater than the rate at which water is flowing toward the well from the land side, since the filtration becomes less perfect, as more water is drawn from the surface source.

When the first ground water supplies were introduced, practically nothing was known as to the causes of iron in the water, and many of the wells or other collecting works were located in such a manner that they were soon affected by iron. In some of these cases it has been necessary to abandon the source, while in other cases filtration has been resorted to.

Good examples of the deterioration of ground water sources, due to the increase in the quantity of iron, are found in Hyde Park, Middleboro, Marblehead, Bradford, Provincetown and Reading. In Bradford and Provincetown the sources of supply were finally abandoned and water obtained from new sources; in Reading and Marblehead filtration has been resorted to.

There are numerous cases in Massachusetts showing the deterioration of ground water due to the increased amount of iron in the water, where the deterioration has been so slow that as yet comparatively little trouble has been experienced, and in some cases, as at Waltham, an apparently successful attempt has been made to check the deterioration by supplementing the supply from some other source so as to reduce the draft. Interesting examples of slow deterioration are found at Waltham and Lowell, where the deterioration is evidently due to increasing amounts of water being drawn from the river, or possibly to more rapid infiltration of water from the river.

In some cases the deterioration is due to the extension of the area from which the water is drawn to the collecting works with the increased draft from the wells. A case of this kind is found in Wellesley, where there is no pollution in the immediate vicinity of the wells, but the chlorine, the index of previous pollution, has greatly increased since the works were put in, due evidently to drawing water from a populated area from which it was not drawn in the beginning.

There are cases where it can be foretold that the water will

TAKEN FROM THE REPORTS OF THE MASSACHUSETTS STATE BOARD OF HEALTH.

PARTS IN 100 000.

Source of Supply.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
Attleboro well	....	.0068	.0043	.0019	.0025	.0024	.0043	.0028	.0046	.0068	.0047	.0069	.0120	.0120	.0062	.0107	.0048
Avon well	.0115	....	.0100	.0020	.0300	.0010	.0047	.0038	.0030	.0058	.0049	.0047	.0042	.0045	.0047	.0045	.0040
Ayer wells	....	.0000	.0163	.0013	.0030	.0000	.0077	.0022	.0050	.0083	.0073	.0112	.0122	.0063	.0087	.0101	.0208
Billerica wells	....	....	....	....	....	....	....	.0101	.0252	.0280	.0287	.0435	.0382	.0432	.0463	.0414	.0362
Brookline. Tap at low service pumping-station	....	....	.0035	.0022	.0018	.0012	.0032	.0022	.0068	.0070	.0084	.0165	.0230	.0215	.0218	.0287	.0208
Cohasset. Wells in Ellms Meadow	....	....	....	....	....	....	.0038	.0027	.0053	.0043	.0046	.0065	.0190	.0050	.0033	.0027	.0040
Easton well	....	.0100	.0025	.0040	.0010	.0000	.0018	.0020	.0025	.0047	.0054	.0055	.0080	.0090	.0142	.0087	.0080
Foxboro wells	....	....	.0010	.0000	.0000	.0000	.0028	.0017	.0040	.0052	.0040	.0095	.0132	.0160	.0067	.0073	.0025
Groton well	....	....	....	....	....	....	.0068	.0048	.0082	.0050	.0048	.0076	.0040	.0095	.0060	.0052	.0017
Hyde Park. Old wells	....	.0112	.0175	.0149	.0141	.0089	.0113	.0107	.0340	.0312*	.0158	.0393	.0501	.0684	.0859	.0720	.0769
Lowell. Boulevard wells	....	....	....	....	.0098	.0222	.0310	.0388	.0591	.0260	.0297	.0317	.0337	.0402	.0439	.0562	.0715
Manchester. Large well	....	.0096	.0010	.0040	.0027	.0017	.0023	.0020	.0055	.0064	.0087	.0081	.0077	.0070	.0115	.0108	.0108
Mansfield well	....	....	....	.0000	.0030	.0040	.0013	.0010	.0020	.0037	.0046	.0029	.0063	.0100	.0065	.0023	.0030
Marblehead. Well No. 2	....	....	....	....	....	....	....	.2972	.3333	.3274	.4900	.2911	.4920	.4380	.4675	.4633	.4771
Methuen wells	....	....	.0050	.0133	.0123	.0052	.0038	.0092	.0223	.0077	.0095	.0322	.0333	.0580	.0365	.0336	.0319
Middleboro well	....	.0070	.0237	.0187	.0288	.0227	.0408	.0329	.0489	.0487	.0841	.0922	.1372	.1170	.1126	.1209	.1349
Monson well	....	....	....	....	.0092	.0123	.0037	.0103	.0045	.0060	.0072	.0072	.0040	.0030	.0033	.0023	.0033
Needham. Well No. 1	....	.0000	.0020	.0000	.0010	.0000	.0015	.0021	.0029	.0045	.0055	.0038	.0038	.0030	.0047	.0050	.0025
Newton. Tap at pumping-station	....	.0119	.0110	.0146	.0108	.0122	.0032	.0028	.0029	.0053	.0057	.0095	.0103	.0137	.0080	.0063	.0053
North Attleboro well	.0158	.0040	.0178	.0020	.0127	.0028	.0023	.0040	.0073	.0120	.0087	.0083	.0082	.0272	.0115	.0090	.0080
Provincetown wells	....	....	....	....	....	....	.2289	.4433	.3774	.3809	.4100	.4713	.6837	.6930	.6787	.9750	.7900
Reading filter gallery	....	.1251	.2642	.2277	.2696	.2644	.2254	.1721	.2497	.2068	.1367	.1715	.2214	.2286	.2560	.2082	.2525
Walpole wells	....	....	....	....	.0015	.0023	.0037	.0020	.0140	.0051	.0057	.0102	.0037	.0032	.0068	.0077	.0036
Waltham well and filter gallery	.0034	.0020	.0044	.0082	.0137	.0108	.0162	.0082	.0086	.0182	.0257	.0305	.0352	.0437	.0439	.0744	.0290*
Ware well	....	.0035	.0010	.0020	.0010	.0045	.0014	.0010	.0042	.0067	.0047	.0032	.0045	.0070	.0090	.0068	.0032
Webster well	....	....	.0032	.0043	.0022	.0030	.0021	.0010	.0036	.0067	.0050	.0116	.0127	....	.0160	.0106	.0092
Wellesley tubular wells	....	....	....	....	....	....	.0068	.0022	.0068	.0045	.0100	.0076	.0107	.0055	.0072	.0059	.0053
Weston well	....	....	....	....	.0019	.0009	.0028	.0078	.0063	.0064	.0080	.0083	.0090	.0057	.0100	.0076	.0062
Winchendon well	....	....	....	....	....	.0047	.0115	.0113	.0112	.0058	.0115	.0156	.0447	.0620	.0627	.0660	.0932
Woburn filter gallery	....	.0004	.0021	.0023	.0011	.0012	.0015	.0015	.0032	.0045	.0048	.0052	.0052	.0038	.0035	.0028	.0032

* Draft from this source reduced by introduction of additional source of supply.

contain iron, and in other cases samples drawn from the test wells with a hand pump will show iron. There are also cases where it is reasonably certain that the water will not contain iron, but the only safe way, before installing a new supply, is to conduct a pumping test, drawing water from the ground at as great a rate as it is likely to be drawn after the works are constructed, and making frequent chemical examinations of the water. Of course the deterioration may be so slow that it cannot be foretold by a test of any reasonable duration, but in that case the deterioration after the works are put in is likely to be so slow that it will be safe to construct the works.

Pumping tests have been insisted upon by the State Board of Health of Massachusetts for many years, and in most of the new supplies, except for the very small ones, which have been introduced in this state for the past ten or twelve years such tests have been made. While in the majority of cases, after the source has been carefully selected, the pumping test has been satisfactory, and it has seemed as though the expense of the test might have been saved, in the few cases in which it has proven unsatisfactory it has been of enough value to more than warrant the expense of all of the other tests which have been made. In his own practice the writer has seen the results of fifteen pumping tests during the past three years, and in four of these the tests have shown unsatisfactory results. It should be said, however, that in each of these four cases the conditions were such that the results were not unexpected, but the test was carried on in the hope that the surface indications might be unreliable.

A pumping test consists in drawing water continuously from the ground at a rate at least as great as it will be drawn after the works have been constructed and are in general use. During the test careful measurements should be made of the quantity of water pumped, generally by means of a weir, and at the same time measurements of the height of water in the ground should be frequently made by means of open test wells located at different places within and around the area from which water is being drawn.

The length of time during which the test should be continued depends entirely upon the results obtained during the test. If

the general level of the water in the ground continues to go down with considerable rapidity, indicating that the water stored in the ground is still being drawn upon, the test should be continued. If, however, the level of the water in the ground becomes practically stationary, and the analyses indicate that there is absolutely no sign of deterioration in the quality of water, a test of one or two weeks may be sufficient. In some cases it has been found necessary to continue the test for periods of many weeks. After the pumps are stopped, frequent readings should be made of the height of water in the test wells to show the recovery of the water level, as without this information the test is likely to be of little value as an indication of the quantity of water available.

The results of the test will require careful interpretation, but when interpreted intelligently a very accurate prediction can be made, both of the quantity and of the quality of the water to be obtained from the source. So far as the writer knows, the results of a properly conducted pumping test have never proved unreliable.

From what has already been said, it is plain that the surface indications do not furnish absolutely trustworthy evidence of what may be found beneath the surface. The surface indications, however, are of sufficient value to warrant careful study before any test wells are driven, and the wells should not be located at random, as is sometimes done.

The sources of the water in shallow wells, such as we are considering, are, the rainfall upon the ground in the vicinity of the well, and water which may percolate toward the source from some neighboring surface water. The very best water generally is that which enters the ground directly from rainfall, since this is more likely to be unpolluted in the beginning and to be less subject to deterioration with increased draft from the source. The amount of water entering the ground depends upon the contour of the surface and the character of the soil. The water falling on steep slopes runs away very quickly and less enters the ground than upon comparatively flat land.

If the soil near the surface is compact and impervious, very little water can enter the soil. The most favorable condition, therefore, for obtaining water from the ground is a flat area of

sandy or gravelly land. When this condition is found, there is usually some place in the vicinity where good wells can be developed, although in some cases even these indications fail.

Ground water, in general, flows in the direction of the surface slopes, although this is not by any means always the case. In general, however, the best place to obtain the ground water is likely to be in some valley, not only because the ground water from the surrounding territory is likely to seek this low point for an outlet, but because it will also be found nearer the surface. Wet land, except when at about the level of the water in a neighboring stream or pond, indicates an impervious stratum, which keeps the water near the surface, and is not a favorable indication. It is usual to find in every town some old resident who will volunteer to assist in locating a well, and will lead the way to some spot which is never dry even in the driest season, which, in his mind, indicates an unfailing supply of water, whereas it really indicates only some stratum of clay or other tight soil through which water passes with difficulty and from which water cannot be obtained by means of wells.

There are times, however, when science fails and the old resident wins. The best ground water supply which the writer has ever seen was found by the superintendent of water works, who was making tests under his direction. He reported over the telephone very unsatisfactory results in the places selected, and wished to try one well near a spring on the farm where he was born. This the writer consented to, without having seen the location, feeling certain that the result would be as usual in such cases, — clay bottom bringing the spring to the surface, — but instead of that, one of the finest water supplies in New England was the result.

Swampy areas, or areas containing a considerable deposit of peaty matter, which is wet much of the time, should be regarded with very great suspicion. If wells are located sufficiently near to them, they almost invariably affect the quality of the water, unless there is an impervious stratum beneath the swamp which keeps this water from entering the wells.

When, as is usual, the ground water source is located in a valley near a stream or pond, a considerable proportion of the water is obtained from the surface source, this proportion depending on

many things, but chiefly upon the rate at which the water is drawn. Water obtained by infiltration from a surface source is satisfactory if conditions are such that it is well purified in its passage through the ground, that is, if the organic matter is completely changed over to inorganic. In many of the satisfactory ground water sources the greater portion of the water is obtained in this way. Such water may have some of the color of the surface source, and the temperature may be somewhat higher than that of a ground water not affected by the surface source, but there is no iron, and the water is bacterially pure.

The bottoms of many of our streams and ponds are covered with a deposit of material which is almost impervious to water, and it is probably due to this fact that the quality of the water obtained from wells located near surface sources is as good as it is.

In the case of Waltham, where the collecting works were located very close to the bank of the Charles River, it was found that wells on the opposite side of the river were affected by the draft of water from the collecting works, indicating that the bottom of the river was comparatively tight. There is, however, in this case, as in practically all such cases, a certain amount of infiltration from the river, very slow, and over a very large area, but sufficient to cause a material increase in the iron in the water.

It is frequently claimed, where works are located near a stream, that all of the water comes from the land side and that none is coming from the river, but such a condition requires an absolutely impervious stratum between the river and the wells, and those who have had occasion to excavate in the immediate vicinity of streams know that there is under all conditions considerable seepage from the stream, even in the small area occupied by a trench. When the level of the water in the ground is lower than that of the water in the river for a stretch of many thousand feet, as it is in many cases, it is impossible to believe that the ground is not fed to some extent by infiltration from the river.

In some of the supplies from wells and filter galleries the water is obtained almost entirely from adjacent surface sources, and when the conditions are favorable, such water is thoroughly purified and almost equal to the best ground water supply.

In some of the recent cases an attempt has been made, which has

proved quite successful, to increase the yield of the ground water sources by application of water to the surface of the ground in the vicinity of the wells. At Newburyport, the water from a stream some distance away is pumped on the gravelly soil above the wells and springs from which the supply is drawn. The water of the stream is of very poor quality, containing an enormous quantity of organic matter during the summer months, but although some of the water is lost, the quality of the filtered water is excellent and the results on the whole have been satisfactory.

A somewhat similar case is at Dover, N. H., where water is obtained from several wells and springs. The water of certain wells is of excellent quality, while that of others contains so much iron that it cannot be used for domestic purposes. In an emergency a rough filter was hastily constructed in the sand in the vicinity of the wells, which gives good water, and the water containing iron was thoroughly aërated and pumped to this filter, from which it found its way through the soil into the wells which contain good water.

It was the writer's intention in preparing this paper to have given some details in regard to the construction of works for collecting ground waters, together with costs and other data, but this must be omitted for the present. It may be said, however, that the cost of the preliminary investigations for a ground water supply is likely to be greatly in excess of the cost of the investigations necessary in connection with the development of a surface source, but the cost of construction may be much less. In one recent case a town, about ready to begin work in the development of a surface source at a cost of $300 000, found that an ample supply of much better water could be obtained from the ground at a total expense of $50 000. But whatever the cost, the superior quality of the water, and, above all, the safety in its use, should cause the ground water sources to be thoroughly investigated before determining upon a supply from a surface source, which is certain to be inferior.

DISCUSSION.

THE PRESIDENT. Gentlemen, you have heard the paper, which, it is proper for me to say, and I think you will all agree with me, is one of the most interesting papers which has been read before this Association for a number of years. I hope there will be a full and general discussion of the subject.

MR. LEWIS D. THORPE.* We constructed a new system in Newburyport last year, the supply being taken from a small tidal river. A dam was constructed, with its crest at an elevation sufficiently high to exclude the salt water, across the stream at a point near its outlet, and from this stream the water was pumped a distance of about two miles and discharged on to natural sand filters. These filters are constructed in a small ravine which is located a short distance away from the main pumping station. In preparing the beds, all the loam and subsoil were removed to the surface of the sand and the sand leveled, the loam and subsoil being used for the embankments. Two open beds were constructed, one having an area of about 30 000 square feet and the other 15 000 square feet. No underdrains were used. The water passes through the filters at a slow rate and is collected in trenches in which vitrified pipe surrounded by screened gravel is laid, and is conducted into a small reservoir located about 150 feet distant and 45 feet lower than the surface of the beds. This reservoir is uncovered, and has a capacity of about 600 000 gallons. From the reservoir the water flows by gravity to the main pumping station, from which it is pumped directly into the city mains. In addition to the open filters, about 5 000 feet of sub-surface filters were constructed for use during the winter months. These filters are of 8-inch vitrified pipe, laid with open joints and embedded in screened gravel. They are laid in four lines, extending around the slopes of the ravine just outside of the open filters, and are about 4 feet below the natural surface. It is not proposed to use the subsoil filters when it is possible to use the open beds. The system has been in operation about one and one-half years, during which time we have pumped about 400 000 gallons per day from this source. From the analysis made by the State Board of Health the

* Civil and Hydraulic Engineer, Boston, Mass.

results have been satisfactory. The water in the river is full of vegetable growth and highly colored, and is unfit for domestic use without filtration. The open beds were constructed for use during the warm weather, but last winter they were used throughout the freezing months with good results and with very little trouble. The depth of sand in the ravine and filters is from 30 to 40 feet, under which is a layer of hardpan, the general slope of which is in the direction of the collecting reservoir. Of the total amount of water pumped on to the beds, about 70 per cent. has been collected in the reservoir during the past eighteen months; the balance I am unable to satisfactorily account for.

Mr. A. O. Doane.* Some years ago, when Newton was putting in a number of wells along the Charles River, I made a large number of temperature measurements of the flow from 2½-inch pipe wells, driven about 20 feet apart to a depth of 40 or 50 feet, and within 100 feet of the river. I found that the temperature in nine tenths of the wells was the ordinary temperature of ground water, about 48 to 50 degrees. This was in the summer, when the temperature of the water in the river was very much higher than that, perhaps at times around 80 degrees in very hot weather. Occasionally one of the wells would be 15, or, in some cases, 20 degrees higher than the wells on either side. This seemed to show that that particular well connected with some stratum which had a much more direct connection to the river than the others, and the low temperature of the other wells showed that the water was coming mostly through the ground for a considerable distance.

We also found that the water in wells driven in the river bed would stand at a higher elevation than the surface of the river. Our observations showed the same condition that Mr. Johnson spoke about as occurring in Waltham, namely, that the wells on one side of the river were affected by the draft on the wells on the other side.

Mr. George E. Winslow.† Mr. Johnson speaks of the Waltham wells in a number of places, and it might be inferred from what he says that a great deal of this supply comes from the river. The basin, formerly called the filter gallery, is about 50 or 75 feet from

* Division Engineer, Metropolitan Water Works, Boston, Mass.
† Waltham, Mass.

the river. When we increased our supply, by building a well some 18 feet deep in this basin, I tried a number of experiments to find out how much water we took from the river.

Before digging this well we made tests with a 5-inch pipe driven about 83 feet deep between the basin and the river. This well would yield with hard pumping 175 gallons of water a minute. As an experiment to see whether this well would add to our supply, I pumped the water into the river for twenty-four hours, noting the level in the basin and the amount of water pumped, the water being kept at the same level in the basin in pumping to our reservoir. I found that in pumping it into the river I decreased the amount of water from its normal condition. I then turned the flow into the basin, and found that I increased the supply. This experiment showed that we could get more water by driving wells near the basin. We concluded, therefore, to increase our supply by putting in a well inside the basin.

The question then arose as to how much water we would get from the river and how detrimental it would be to draw so much water. So I suggested the idea of putting a driven well over on an island across the river, the well being about 1 000 feet from the basin. I was laughed at a good deal, however, for having an idea that I could draw water from that island into our well. While building the new well I had readings taken on the island three times a day, and I found that we lowered the water there to a maximum depth of 2.8 feet below the water in the river. When we were not pumping, the water came back to its normal height, which was 0.2 of a foot above the water in the river, making a total of 3 feet that we lowered the water in the well 1 000 feet from the basin and across the river. So we were satisfied that we did draw the water from there.

Furthermore, Mr. Noyes, formerly city engineer of Newton, told me that we went a good deal further than that. He said, " You lower the water from six inches to a foot in our Auburndale wells when you are drawing your well down to the lower level and holding it there." Those wells were two miles from the basin.

Experiments were tried to find out how much water came from the river by making tests of the temperature of the water in the basin and in the river. When the water was drawn down and the

men were at work shoveling the earth out, I got temperatures of 52, 53, and 54 degrees, according to where I put my thermometer in the basin. There was a slight difference there, very little of it being up to 54 degrees. When it went from the pumps — there were seven centrifugal pumps working, three of them 8-inch and four of them 6-inch pumps — it ran through a weir to the river; at this weir the temperature was 54 degrees. Of course I don't say that that was the temperature of the water normally; it was the temperature of the mixed water as it came from the basin, increased perhaps a little by friction in its passage through the pipes and the pumps. The water in the river at that time stood at 72 degrees, and we got a rise of 2 degrees from the different causes.

Now I don't know, and I don't know of anybody who can tell me, how much of that water came in from the river under the conditions I have named. I know that it would take a lot of it to bring it up the last 2 degrees, but a very little to bring it up the first 2 degrees, so I am satisfied that there was but a very small amount of water came in from Charles River.

Mr. John H. Flynn.* I would like to ask Mr. Johnson if he has had any experience with the witch hazel stick, and if so, what his experience has been and what he thinks of the man who manipulated the stick?

Mr. Johnson. I have seen many successful wells located by the witch hazel stick, but the stick was always handled by a pretty clever sort of a man, who knew where to look for water.

I had thought that the witch hazel stick had gone out of business, but I ran across a case last summer where a well had been located in that way, and the owner, although rather skeptical about the witch hazel, considered the results marvelous. The owner described how the man wandered around aimlessly with the stick, and finally came to the bottom of the valley, where he paused, went back and forth, and seemed to have found something. Finally the stick went over, and the man dug his heel into the ground and announced that there was water there. This he did three times, locating three different springs within a radius of five or ten feet. When the well was dug, there were the three streams of water entering it as prophesied, much to the amaze-

* Boston, Mass.

ment of the owner. The springs dried up in summer, however, so that another well had to be dug in a more favorable location, but the witch hazel stick had not failed.

I would like to add something to what Mr. Thorpe has said with reference to Newburyport. The impossibility of telling from surface indications what there is beneath the surface was well illustrated there. The area on which the water is pumped is a gravelly hillside sloping rapidly toward the Merrimac River, the top of the slope being at least 75 to 100 feet above the water of the river. The soil appears to be sand and gravel, and the only visible outlet for the water is a ravine with steep sides, which cuts into the bottom of the hill. In this ravine there is a natural spring, which has been one of the sources of water supply for many years. To make certain, however, that the water would not go in some other direction when it was put on this gravel slope, test wells were driven all over the slope. It was found that, even on the steep slope leading toward the river, some of the ground water evidently went in a direction opposite to the slope and away from the river.

In the ravine near the foot of the slope and below the natural spring, it was proposed to construct a cut-off dam to prevent the escape of any water through the ground, and test wells were driven every few feet across the ravine in order to determine the necessary depth of the cut-off dam. These test wells indicated that the ledge followed the contour of the surface quite closely, so it was proposed to carry the cut-off dam down to the solid ledge. When the cut-off wall was built, however, it was found that what appeared from the test wells to be ledge was simply a mass of loose bowlders, every one of the test wells which had been driven to find the ledge having struck on one of these stones. This experience simply shows the unreliability of surface indications, and that at times even test wells may give a wrong idea as to the formation beneath the surface.

Mr. Harold K. Barrows.* I was especially interested in what Mr. Johnson said regarding the testing of wells, and his opinion that a ground water supply should be tested by pumping, if practicable, up to or beyond the amount of the probable future con-

* Hydraulic and Sanitary Engineer, Boston, Mass.

sumption. I think this is excellent advice. In case it is not practicable to carry the pumping test to this extent, it is of interest to know something about the manner of predicting the probable future yield.

Prof. Charles S. Schlichter, of the United States Geological Survey, has investigated very fully along those lines, more especially in the West, and has developed some complicated formulæ (to which, I presume, Mr. Johnson referred) applicable in studying the direction of flow and amount of ground water available, which are not of much practical service to the engineer. He has, however, gone further and evolved some practical results. [See Water Supply Paper 140, United States Geological Survey, page 86 *et seq.*] He defines the *specific capacity* of a well as the amount of water furnished under a unit lowering of the surface of the water in the well by pumping. Thus if the water in a well is lowered 2 feet below the natural level by continuously pumping from it, at a rate of 20 gallons a minute, the same well may be expected to yield approximately 40 gallons a minute if the water is lowered 4 feet below the natural level. He further states that for shallow wells the yield will not increase in this direct ratio, but will be considerably less on account of the decrease in percolating surface due to the lowering of the water-plane in the neighborhood of the well.

It is likely that Professor Schlichter's conclusions are not generally applicable to our New England conditions, where there are frequently many changes in strata and material in comparatively short distances. There is a dearth, however, of reliable data from pumping tests of wells under various conditions, and if such information were at hand in systematic and comparable form, analysis might enable some conclusions to be drawn that would be of service in predicting the probable yield of a well from a pumping test with a delivery less than the future amount required.

Another subject of interest in connection with ground water supplies is that of large wells. We do not often hear of wells of large diameter being built, the ordinary method being to drive a number of wells of comparatively small diameter. Usually the latter is most economical, especially in first cost. Now, are there not sometimes locations in which a large well may in the long run better suffice to provide a water supply? What I have in mind is

a case where the material is a rather fine sand, which does not yield the water readily, and where the reservoir capacity of a large well would be a distinct advantage; that is, it would be filling while the pumps were not in operation. I should be interested to have this subject discussed at greater length, especially in regard to the cost of such wells and methods used in their construction at different locations.

MR. WILLIAM F. SULLIVAN.* Mr. President, I was interested in the question and remarks of Mr. Flynn with regard to the so-called witch hazel experts or water smellers. I was on a job where they employed a marvel of a man, who claimed to possess powers and wisdom beyond the ordinary mortal when it came to locating ground water. A cruising party, including the fellow with the divining rod, started along and parallel to a river bank on a path leading across a small footbridge covered with sand and dirt and fringed on both sides with bushes. Under the bridge flowed a small, swift-running brook. The "wonder" had a stick in his hand, feeling happy and looking wise. As he crossed the bridge the stick did not show any agitation or indication of water. We called his attention to the lack of sensitiveness of the rod. He appeared embarrassed, but explained it away by saying that surface water had no effect on the rod or the electricity in his body. We continued further along and led him directly over a spot where a few days previously we had driven and washed down a test well 90 feet deep, which yielded 50 gallons per minute. The pipe had been pulled up and a twig thrown over the hole in the ground. Again the divining rod failed to detect, this time, ground water. After being told that there was an abundant supply there, he tried again, and he reckoned that he had not been holding the wand just right. About this time he was somewhat of a discredited prophet.

From the man's talk and explanations, I came to the conclusion that this particular wonder-worker was only a poor human being like ourselves, not even possessing the knowledge we had, as we had samples of the strata to guide us on our hunt for water. I believe that he worked on the assumption that water underlaid the surface of the ground in large or small quantities almost everywhere, particularly where the surface indications showed large

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

deposits of sand and gravel; and that, in case of rock formation, the drill would sooner or later strike a seam below the water table; that this fissure would ramify off in different directions and permit more or less water to percolate into the well. Experience has proven this assumption correct, as there is water in the different kinds of material, such as clay, sand, and gravel, below the water table, the question of quantity depending on the porosity of the material if backed up by sufficient drainage area or an adjacent surface supply.

Mr. Johnson speaks about test wells and subterranean streams. I have always believed that these so-called subterranean streams were nothing more or less than water percolating through coarse material to a lower level, and that certain reports which give the impression that you could float a log through an underground channel were erroneous and misleading. The subterranean basin, however, is present wherever you are able to get water from a well. The extent and capacity of a basin depends on the extent of the deposit of sand, gravel, or other water-bearing materials and the percentage of voids.

My experience has been that test wells show the extent of a subterranean basin and how much it is affected by pumping, and its recuperative powers. Test wells also show that the water feeds into the basin from different directions and at different rates of flow, and that the frictional slope is not the same in all directions from the well system, showing in the average well plant that there is a freer passage in some directions than in others, and that subterranean basins do not draw down uniformly around a gang well system.

In regard to temperatures, my experience agrees with Mr. Johnson's. In some well supplies, the temperature in the spring is between 48 and 50 degrees as a minimum, and, as the season advances to the summer months, the temperature increases to about 67 degrees, while the temperature of the surface water is about 75 degrees. When the temperature of the surface water drops in the fall, the ground water continues warm until about November.

I would like to ask Mr. Johnson if he can give the reason why, when a gang of wells are being pumped and the temperature of the water from the gang wells is 65 degrees, an individual test well

located within the zone of the draft, say, within ten feet of the well system, has an almost uniform temperature throughout the year?

Speaking of imperfect filtration and the deterioration of water from wells, I would like to ask Mr. Johnson if he knows, in the case of a well plant located near a stream or pond, the analysis of the well water indicating imperfect filtration, whether or not all of the filtering material that lies between the wells and the surface water is affected? In other words, has the material as a whole become imperfect filtering material, or is it just a small portion around the open end or around the strainer of a well? To put the question in another way, if you should move such wells five or ten feet and keep the same location of the suctions or well lines, would the water be as good as was obtained when the plant was first installed?

Mr. Flynn. Mr. President, I am a little interested in this witch hazel matter, for I claim to have a certain gift in that direction myself. In this city we have four wells which I located by a stick. We use them instead of ice for lowering the temperature of water for drinking purposes. In every case I found water where the stick indicated that there was water, and I found it at the temperature of 50 degrees. Within two months I have located a well for the tuberculosis camp in West Roxbury. They wanted water out there, and we didn't have any water within quite a distance of them, and it would cost something like $8 000 to have the water main extended to their camp. I didn't use the witch hazel stick in that case. I went over to a house across the street from where the camp is and I cut a twig off an apple tree, and I found it would work just as well as the witch hazel. It all depends on the man behind it. Now, there is something in this. Nobody has ever explained what it is, whether it is the magnetism in the man or in the stick, but of course I claim it is in the man. I will tell you how it has worked with me. In two or three cases where there were strong indications of water, and where I got water very close to the surface of the ground, and an abundance of it, I held the stick in my hand and did my utmost to stop the stick from going down; I tried to keep it from going down, but it went down in spite of me, turning and leaving the bark in my hands.

Mr. John C. Whitney.* I should like to ask Mr. Johnson why the inflow of surface waters into a ground water supply located near a stream should largely increase the amount of iron in that ground water?

Mr. Johnson. First, Mr. President, in answer to Mr. Barrows' question in regard to the use of large dug wells, I would say that I think there are many places where a large well is much better than driven wells. There are other places where a large well would be better if it were not for the greater cost. In rather fine material, or where for any reason the flow through the ground is somewhat slow, it is a great advantage to have a large quantity of water stored in the well to supply the pumps. At the end of the pumping the well may be drawn to a low level, but it will recover before the pumps are started again. There are other places where the water-bearing stratum is so shallow or so near the surface that driven wells are not practicable, for when you draw water from the driven well the water level is lowered a good many feet in and immediately around the well, the distance depending upon the character of the material in which the well is driven and the rate at which the water is drawn. If a sufficient depth of water cannot be secured, it is better to dig a large well. The advantages of the driven wells are, first, their small cost in comparison with the cost of a large well; and, second, the comparative ease with which the driven well system can be extended to draw water from a large area.

In regard to foretelling the amount of water which can be obtained from the ground by pumping at a slow rate, I would say that I have never been able to do it. Undoubtedly, if the porous material from which the water is drawn were of uniform quality, and extended for a long distance in all directions from the well, it would be perfectly possible to make such computations. In practically every case of which I have any knowledge in this part of the country, the conditions as to the character of the soil and the depth and direction of the different strata are so complicated that it would be an absolute waste of time to attempt any such calculation. In some cases with which I am familiar the water is drawn from a pocket of porous material surrounded by impervious mate-

* Water Commissioner, Newton, Mass.

rial, and the volume of water which could be obtained could not be increased by lowering the level of the water in or around the wells. In other cases the wells are situated near or in a large deposit of sandy soil, and by lowering the level of the water in the wells a few feet a great increase is made in the area affected by the wells and in the quantity of water flowing toward them. Some time ago I made the prediction, based on information obtained from studying the quantities of water previously drawn and the corresponding changes in the level of the water, that a certain well would yield about 250 000 gallons per day in a very dry season. During the last two summers, which have been very dry ones, water has been pumped from that well at the rate of about a million gallons per day, and it became my unpleasant duty to explain this discrepancy in a town meeting a short time ago.

Mr. Sullivan asks why the temperature of a test well somewhat off the line of wells from which water was being pumped should be low and the temperature of the gang wells high. This probably means that the water coming from different directions toward the wells has different temperatures, and the test well which he speaks of as having a low temperature was in the vein which came from a district furnishing cold water. If the gang of wells was beside a surface source, I would say that much of the water came from the surface source by direct or indirect filtration, but the test well was in a vein of water which was either coming from the land side and not from the surface source, or was coming more slowly from that source.

I do not think moving the wells affected by iron further away from a stream would do much good unless they were moved a considerable distance. The appearance of iron is not due to the deterioration of the filtering material, but rather to the change in the rate of filtration or the draining of the water through some new channel. It is just the same as if Mr. Collins increased the rate of filtration of the Merrimac River water at Lawrence. He would get poor results. If the rate were sufficiently increased, he would undoubtedly get iron.

Where wells are located a sufficient distance from a surface source so that water is drawn from that source over a large area, as

in the case of a location near a stream, where the water may enter the ground for several thousand feet above and below the wells, the water is not likely to deteriorate very rapidly.

Mr. Whitney's question as to the reason why the entrance of surface water into a ground water supply located near a stream should increase the amount of iron in the ground water is a somewhat difficult one for me to answer as it involves considerable chemistry. In a general way, it means imperfect filtration of the water. Exactly the same result is seen when sewage is applied to sand filter beds at too rapid a rate or in too large doses. One of the first indications of such abuse of a sewage filter is the presence of iron in the effluent. No water which contains oxygen or air, contains iron, since the oxygen will unite with the iron, forming an insoluble oxide which is left behind in the soil and which sometimes gives the soil the appearance of iron rust. Perfect filtration means that there is always sufficient oxygen to burn up the organic matter. Now when you draw water from a pond containing a lot of organic matter through a bed of mud on the bottom, there is not sufficient air in the water to provide the requisite oxygen for burning up the organic matter, and it is necessary that there should be an opportunity for oxygen to get at the water as it is drawn through the soil before it enters the well, or there will be iron in the water. This is a simple explanation, but I believe it does not tell the whole story chemically. The further away the wells are located from the source of the water containing organic matter, the less chance there is of getting iron in the water, because it gives so much more opportunity for the oxygen, which is normally present in all sandy soil, to get at the water.

Mr. Robert S. Weston.* The chemistry of iron in ground waters is rather a complicated subject, and I know of no simple statement of the conditions which would be better than Mr. Johnson's. Those waters which contain the least iron are those which have had the most oxygen admitted to them during their history, either before or after they come to the surface of the ground. The decomposition of the organic matter in the ground uses up the oxygen and produces gases which dissolve the iron. Iron-containing waters, when exposed to the air, rapidly absorb

* Consulting Engineer, Boston, Mass.

oxygen, which, in the course of time, causes the iron to rust, that is, to become insoluble and precipitate. This precipitation is helped or hindered by various factors, a description of which would require too much time.

There is one point in connection with Mr. Johnson's paper which I would like to emphasize, and that is the necessity of conducting pumping tests, not only through a dry, but through a fairly wet, season, especially when wells are located near meadows. In these cases the water coming from the highest side is apt to be very good, while that coming from the meadows may contain iron in a form difficult to remove, especially after a sudden shower has fallen upon this meadow or it has become flooded by an overflow. In these cases the water seeps down through the peaty matter in the meadow, dissolves out the iron, and contaminates the water. This contamination might not reveal itself if the pumping test were conducted through a dry season only. It would be well in all cases to continue the pumping tests well into the wet season. The more information one can have regarding the quality of the water in addition to a knowledge regarding the quantity of the water, the better.

I am very glad that Mr. Johnson has emphasized the fact that one man can see underground about as far as another, and that in New England the water-bearing sand and gravel exist in pockets and not in layers, as they do in other countries and in other parts of this country.

Regarding the infiltration of pollution from surface sources into filter galleries and wells located alongside of them, there is some difference of opinion. The fact was denied a few years ago by many advocates of ground water, but recent experiments have shown that such infiltration does occur, and the amount is a function of the differences in level of the ground and surface water, the thicknesses and sizes of material through which the water has to pass, and the rate of pumping. In Dresden slight pollutions of the ground water supply have followed floods of the Elbe. In northern Germany wells near drainage canals have proved bad, while those some distance away have furnished good water.

Mr. Harry W. Clark.* Nearly all soils and gravels contain

* Chemist, Massachusetts State Board of Health, Boston, Mass.

iron in combination with silica and other mineral substances, and if a water containing organic matter enters the ground from a pond or river with not sufficient oxygen present to oxidize this organic matter, it takes for this oxidation oxygen from these basic oxides in the soil, reducing them to a soluble form. When the water is exposed to the air, ferric hydrate if formed and precipitates. The presence of iron is not, I believe, a question of distance; it is simply due to the fact that the water does not start with enough dissolved oxygen to oxidize the organic matter present.

Mr. M. N. Baker.* I was particularly interested in Mr. Johnson's statement relating to the percentage increase in ground water supplies from 1879 to 1909 in the state of Massachusetts. This has occurred to me as in part explaining it: In 1879 there were in Massachusetts, as in the other states of the Union, a comparatively small number of water works, and they were divided into two classes, broadly speaking. One was for the larger cities, that might not so readily draw upon ground water for their supply; and the other class of water supplies was for the smaller places, many of which had originated early, when there was an opportunity to bring in a small gravity supply from some near-by source. Pumping was not involved.

In the course of time a large number of water works have been built, and in the last few years the new works have been almost wholly in the smaller places. For the smaller places it is very much more feasible to develop a ground water supply than it is for the larger places. It seems to me that that might in part account for this percentage change.

Unquestionably the arguments which have accumulated in the last few years in favor of ground water supplies as against surface supplies, on the point of superior quality, have had a great deal to do with the percentage increase in the ground water supplies, and deservedly so. I think it is worth noting, perhaps, that there has been the same general increase in the percentage of ground water supplies in other parts of the world, and that it has been noticeable in Germany. There, if I am correctly informed, there has been in the last fifteen or twenty years a very remarkable turning to ground water as a source of supply. This has even had

* Editor, *Engineering News*, New York.

governmental sanction, if not official pressure, including even the personal influence of the emperor of Germany.

There is an attitude of the Germans in regard to water supply, and particularly in regard to stream pollution and sewage purification, which I think we ought continually to bear in mind in this country. I noticed when I was in Germany, and it has come to my attention from time to time since, a letting up in the attempts at a high degree of sewage purification, and an accentuation and a greater insistence upon the purification of all water supplies. I think the movement for ground water supplies in Massachusetts and elsewhere is largely a recognition of the fact, as is so well brought out in the paper, that we cannot depend upon surface water supplies in point of purity unless we resort to purification. Now the more we follow out that line, the more, I think, we will see modifications in the attitude of the people of the country towards sewage purification. We have got to have sewage purification in order to protect many of our streams, but we must get away from the popular idea that we can purify sewage so as to make it a safe drinking water.

There is a very extensive German literature on the science of ground water flows and on the yields of wells. Underground water flows have also been studied by the United States Geological Survey, and while, as it has been very well put, those studies have far greater significance elsewhere than in New England, yet they have significance. Those who wish to be guided by all that is available on the subject should have recourse to the German literature and also to the quite voluminous literature that has been published by the Water Resources Branch of the United States Geological Survey.

Mr. Sullivan. There is one other matter connected with well supplies that has always impressed me, and that is the cost of maintenance, the cost per million gallons pumped, and the yearly cost of a ground water plant as compared with the cost of a filter plant, the cost, so far as I know, being much in favor of a well plant.

Prior to the time the State Board of Health took up the matter of water purification, a town or city installing a water supply could go to almost any stream or pond and take its supply and

take it raw. Now that has all been changed. It is almost compulsory, and rightly so, that supplies should be pure and wholesome, and the cost of getting a pure supply, in many cases going miles for it, where once it could be obtained near at hand, and the enormous costs of pipe lines, storage areas, and dams for surface supplies, make such works prohibitive in many instances. First-class and up-to-date filters are expensive, and where unpolluted surface supplies are not available, or where a suitable well supply cannot be found, filters are necessary.

On the other hand, where a well supply can be found, it is usually adjacent to a city or town, and can be installed at a low cost. Well supplies have solved a difficult problem for many towns, cities, and industrial concerns.

In regard to the comparative cost of obtaining a water supply from surface sources, filters, or wells, I would like to ask Mr. Johnson if he has any comparative figures showing the cost of installation per million gallons. Also, whether he has any data showing the comparative cost of maintenance of well plants, as against the cost of filter plants, say, for about a pumpage of five million gallons per day.

Mr. Johnson. I haven't any such figures. Of course, the difference is great because a well plant, as has been said, costs very little to maintain, much less, probably, than the cost of maintaining the mechanical parts of a filter plant. In addition, you have in a filter plant the cost of removing and cleaning the sand and the cost of constant attendance.

Mr. Sullivan. I would like to ask Mr. Johnson if a well plant is not less liable to accidental pollution than a filter plant?

Mr. Johnson. Unquestionably. It is hard to conceive of any serious accidental pollution of a ground water supply, while it is always possible in a filter plant by ignorant or careless operators to let impure water pass the filters.

Mr. Weston. Mr. President, Mr. Sullivan might be interested to know that the cost of a ground water supply with a plant for removing iron would be less than the cost of a surface water supply with sand filtration.

Mr. M. F. Collins.* We have a good opportunity in Lawrence

* Superintendent Water Works, Lawrence, Mass.

to judge of the cost of operating a filter plant. On our open filter the cost of maintenance will run anywhere from $5 close to $6 per million gallons. On our new covered filters we have kept a pretty accurate account of the cost of operation, and we can operate them for a little less than $1.50 per million gallons. That shows clearly what a benefit there is in having a covered filter, where you eliminate ice formation in the winter. Another advantage is that you are able to enter it at any time for cleaning, whereas with the open filter you have to depend a great deal on the weather conditions.

We have had a little experience up in Lawrence with driven wells. We spent somewhere in the neighborhood of $6 500 in experimenting with them. Mr. Johnson speaks about the superior knowledge of some of the oldest inhabitants as to just where water can be found. We have had a few of this type of citizens to contend with. One of them had a plant which he knew would give the city of Lawrence 10 000 000 gallons a day easily. We went up and tested his wells without favorable results, and he came down and complained that we didn't give them a fair test. He was on an elevation of some forty feet above the Merrimac River and had a spring from which he was selling water to the citizens of Lawrence. He claimed he was getting his water from an underground source which came from Vermont, flowed through southern New Hampshire, and thence down to his place. How he got that knowledge, I don't know; probably Mr. Johnson could tell. [Laughter]. The city government felt that we ought to give his spring another test, so we fortunately obtained the late Mr. Smith, a very good, reliable, honest man, to make tests for us. We went up there again and drove some three or four wells, and did succeed in one of them in getting about six gallons a minute. In the others we couldn't work the pump handle at all, it was so air-bound.

There was another gentleman who had a lot of land partly in Lawrence and partly in Methuen, where the two police officers lost their lives, who said that he had water enough in his plant to supply Lawrence for the next one hundred years. So, at the request of the city government, we sunk two wells, one about thirty-eight feet, and the other about forty feet deep. We pumped

for an hour and didn't get a gallon out of either one of them, so that gentleman's theory was knocked in the head.

When you are working on tests of this kind, it is astonishing how many people know just where water is to be found, and how much will be furnished. A German came down to the office one day and told us that he lived near a place called Sow Brook, pretty near the Methuen boundary line, and said that there was a fine flow of water there, sufficient for the city's need. He went before the water board and the members of the city government, and they requested us to go up and sink some wells. We went up and happened to have the city engineer with us. We saw the German and he told us he didn't know so much about it as his wife, but his wife knew there was plenty of water there. We went and saw her, and she showed us the water flowing, and said she had no doubt that it would supply the city of Lawrence easily. But there wasn't water enough to fill a 3-inch pipe, and when we told her how much we wanted, she admitted her ignorance on the subject.

Mr. George A. Stacy.* Mr. President, speaking of people who know where underground water supplies are, I recall to mind a little experience we had when we were looking for our additional supply. There was a good man, an old citizen of the town, who had quite an area of land near the city, and there was a spring on it. He was satisfied that it was a never-failing spring, such as we often hear about, and that it would be foolish to go to work and spend $200 000, and some said $1 000 000, for another supply when one was right there running to waste, and so high that part of it only would have to be pumped. Of course, we had very serious doubts in regard to it, knowing the condition of things, but he made so much talk that the members of the city government, not having had a chance to investigate such things as much as we have, were rather uneasy for fear we might make some mistake, and so we agreed to test the well.

We went up with a common 3-inch diaphragm pump, such as we use on the ditches, and put two men at work. We set up a little weir and we pumped one afternoon. We pumped this well down to within about two feet of the bottom and held it there

* Superintendent of Water Works, Marlboro, Mass.

with very little work all the afternoon. The old gentleman was quite elated. He was a man whom we all respected, and he believed just what he was talking about, that there was water enough there. In the morning the well was full again. Then he thought he had the real thing, sure. But we went up there and put in two pumps the next day, and in the middle of the afternoon the well would supply one pump part of the time only. The result was that after that day's work that well, or spring, didn't fill up again, I think, for about thirty-six hours, showing what the actual flow was. We went to all that trouble, knowing what the result would be, to demonstrate that this nice old gentleman was wrong in his idea and didn't know as much about water supplies as some other people who had made a longer study of the matter. We all run up against that sort of thing at times, and we have to cater to it to a certain extent in order to satisfy the people as to the true facts in the case.

REPORT OF THE COMMITTEE ON THE DEPTH OF LAYING WATER PIPE.

[*Read December 8, 1909.*]

NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — Your committee on the depth of laying water pipe, appointed at the annual convention of 1908, begs to submit the following report.

Three hundred and twenty circulars of the form shown in the appendix have been sent out, to which ninety replies have been received. The information required by the circular was of two classes, the first comprehending general data in regard to local conditions and practice in laying water pipe, and the second covering the results of particular experiences in freezing.

Concisely it may be stated that the result of the investigation made by your committee is largely negative in character, — that is to say, it appears that freezing has not occurred at the depths generally adopted for laying water pipe. Whether these depths are excessive, however, cannot be predicated from the information at hand, because where freezing has occurred there has always been an obvious explanation, usually little or no velocity, and an analysis of these explanations and of the local conditions pertaining does not finally justify any general deduction as to necessary depths.

Considering the results of our investigation in greater detail, reference may be made to the appended tables which summarize the replies received to the questions of the circular. While these replies do not provide the information necessary for conclusions of much practical value, it is believed that there is sufficient information contained therein to make their publication worth while. There is little doubt that if a more general response to the circular had been obtained something of real value might have been worked out and it may be that the presentation of the data now collected will provide a basis for future work and stimulate further study of the problem.

Table 1 shows the replies to the questions asked in reference to local conditions and practice, and Table 2 gives the information obtained of actual cases of freezing. From these tabulations it is apparent, as already stated, that in general the depths now used are sufficient to prevent freezing, but it is less evident whether or not these depths could safely be reduced. Either it must be concluded that present standards express the results of a gradually developed experience and that the present depths are the least which would be safe, or else there is a possibility of lessening these depths without danger. This conclusion is indicated from the fact that with practical unanimity all replies state that the present depths are sufficient, and a considerable number suggest that lesser depths might safely be used. Whenever freezing has occurred it has been largely at night or where there was practically no current, and it is believed that where there is a velocity, say, in excess of one quarter of a foot per second, and particularly in the case of ground water supplies, depths somewhat less than those now used would generally be safe. In main feeders, and in those portions of the distribution system where there will be an assured circulation, the question of minimum depths should be given careful consideration. It is not in the mains but in the services that most of the trouble from freezing occurs, and in the services such trouble usually results from skimping by plumbers or contractors, resulting in the actual laying of the services at depths considerably less than the mains. There is a strong feeling apparent that services should be laid by the municipalities.

Twenty-eight of the places replying report the tapping of service connections on the top of the main, 39 on the side, 12 on the quarter, and 7 in various ways. Freezing of services generally starts at the house and backs out into the main, and it is believed that if services were tapped on the side of the main and then dropped to the depth required to meet local conditions, the lessening of the depth at which the main is laid to that justified by the velocity of the water in the main would not result in increased freezing of services.

In determining the depth of pipe, the character of the soil and of the surface of the ground are factors of some importance. In but very few places, however, from which replies were received is the nature of the soil taken into account in deciding as to the necessary

TABLE 1. — PART 1.

GENERAL DATA.

No.	City	Temperature, Degrees Fahr.: Mean Yearly Temperature	Mean Temperature Coldest Month	Extreme Minimum Temperature and Date of Occurrence	Minimum Temperature at Source of Supply and Date of Observation	Location of City: Distance from Ocean, Miles	Elevation above Sea Level	Source of Supply, Surface or Ground Water	Method of Distribution, Gravity or Pumping	Elevated Storage with Pumping System: Whether Reservoir or Standpipe	Size and Depth of Reservoir or Standpipe (In Feet)	Reservoir or Standpipe Open or Covered	Capacity of Reservoir or Standpipe in Relation to Daily Consumption	Hours of Pumping Daily in Period of Minimum Temperature	Approximate Hourly Rate of Pumping during Winter Months	Does Pumping Entirely Cease at Night during Coldest Weather? If Not, Give Minimum Hourly Pumping Rate
	MAINE															
1	Auburn		10			20	210	Both	Both	R	240 x 240 x 18	O	21 days	8	10	Yes
2	Bangor					40		S	P	S	60 x 75	O	1 500 000 gals	24	24	No
3	Brewer					40±	25±	S	P	S	30 x 100	O	528 000 gals		24	
4	Rumford	42.5	18.1	-24		85	450 to 600	G	P	S	30 x 50	O	½	24		No
	NEW HAMPSHIRE															
5	Dover		-24			10		S and G	P	R	2 500 000	O	3 days' supply	8	9	Do all pumping at night
6	Manchester		-10	-10		40	900	S	P	R				12	13	Yes
7	Nashua	43.9 for 2 yrs.	19	15 (Feb. 14)	-15	40	150	G	P	R	Circular, 15 deep, 4 000 000 gals.	O	¼	12	250 000	Yes
	MASSACHUSETTS															
8	Billerica	49	Temp. of water 50	48	18	20	111	G	P and G	S	25 x 118	C	4	4	1	Yes
9	Boston	51.5	26.8 (Feb.)	-2 (Feb.)		On ocean	18 to 250	S		1 R, 2 S	R, 3.1 acres, 20'; S, 24 x 40	O C	½			
10	Brookline					4	10 to 365	G	P	2 R S	102 x 333 x 21, 94 x 94 x 18; 50 x 30; Cons. 3 500 000 to 1 700 000	C	6 507 000, 1 213 000, 450 000	16	175 000	Yes
11	Cambridge							S	P	R	4 300 000	O	3 to 4 times	15		Yes
12	Fitchburg	46			20	50	400 to 700	S	G	R	152 A 45' deep	O	155 000 000			
13	Fall River					20	270 H. pt.	S	P	S and Tanks	4 tanks 37 x 73; 56 x 65, 56 x 65, 56 x 55. 2 S, 42 x 60	O	5 314 757 Total daily cons. 4 944 914	24		No
14	Hyde Park					6	35 to 200	G	P	S	35 x 50	C	50%	24	24	No
15	Lowell	48.7 47.9	30, Air 38, Water			25	90	G	P D and to Res.	R	30 000 000	O	5 days	24	24	No
16	Lowell (Locks and Canals)							S	P	R	170 x 170 x 16	O	10.5 times	10.5	300-400 gals. per min.	Yes
17	New Bedford	48.5	18.6	Below zero, but not for long	-13 (Jan., '07)	Ocean	0 to 164	S	P	R	500 x 1 000 x 20	O	18 000 000 capacity 7 800 000 av. cons 15 000 000 during freezing weather at times	24	10 000 000 in 24 hrs	Every night except Sunday unless cons. is unusually heavy then operated Sunday night.
18	Reading					10	100	G	P	S	30 x 100	C	530 000 capacity	5	31 000	Yes
19	Sharon					18	250 to 520	G	P	S	20 x 80	O	336 000 capacity	4½	30 000	Yes
20	Springfield	[illegible]	7.7	23 (Jan. '07)	40 (Jan., '04)	100	73 to 200	S	G							
21	Stoughton							S	P and G	S	30 x 60	C				Yes
22	Westfield	[illegible]	23	12 (Feb., '06)	36 (Feb. '08)	100	140+	S	G				40 times daily cons.			
23	Worcester					44	485	S	G	R			2 520 000 cap. 5 500 000 cons.			
	CONNECTICUT															
24	Bridgeport		+20	7		Ocean	10 to 45	S	Both, mostly G	R	250 000 000, 195 000 000	O	12 to 15 days' supply either reservoir	12		Yes, but gravity supply is immediately substituted
25	New London	50				3	0 to 150	S	P and G	Both	R, 100 x 100 x 10; S, 25 x 26	O	Together about 1 day's supply for high service	24	18 000	14 500
26	Norwich					15	0 to 230	S	G							
27	Rockville					150	500	S	P and G	S	40 x 60	O	317 000	5 to 6	5 to 6	Yes
28	Wallingford					12.5	50 to 180	S	G							
	NEW YORK															
29	Canandaigua	50	20	5 to 10 (Feb. '04)	5 to 10 (Feb., '04)	230	686 to 800	S	P	R	Top 298 x 178 x 12 deep	O	4 days	12	1 000 000	Do not pump nights or Sundays
30	Woodhaven Water Supply Co. New York City					5	1 to 30	G	P	R	One 7' 6" deep, one 12' deep	O	2 days	24	21	No
31	Waterford	48.2	14.8 (Jan., '04)	21 (Jan., '04)	21 (Jan. '04)	100	40	S	P	S	40 x 51, 24 x 85	O	32 hrs.	16	45 000	Yes
32	Yonkers	[illegible]	28.7	6 (Feb. '96)		30	0 to 450	G and S	P	Both	R 22 deep; S 100	O C	8 days; Cont. pumping	16 Cont.	16 Cont.	Res. Yes
	PENNSYLVANIA															
33	Lewiston					300	700	S	G							
34	Mauch Chunk	40.7	18.1	14 (Feb. '99)		100	520 to 900	G	G	2 R	2 350 000	O				
35	Monessen	[illegible]	11.8	20		400	750 to 1 150	S	P	R	65 x 30	O	1 day		60 000	45 000
36	Reading	51.5	22.5	11		60	251.5	S and G	P and G	R	H S, 144 x 170 x 25, L S, 248 x 170 x 16, P S, 570 x 342 x 27	O				Yes at times
37	Shamokin					175	750	G	G				262 000 000			
38	South Pittsburg	52.0	30.6	20	[illegible]	300	710 to 1 250	S	P	S	25 x 150, 60 x 30, 25 x 50, 40 x 50, 24 x 16, 40 x 35	O	2 220 000, ½ day	24	230 000	170 000
39	Westmoreland Water Co. (Greensburg, Youngwood, Jeannette, Penn Manor, Irwin)	48.[illegible]	25	1 to 22 (Feb., '99)		350	1 000 to 1 300	S	G		Greensburg H. S., 2 000 000, Greensburg L. S, 486 000 000, Jeannette, Penn Manor, Irwin, 76 000 000			0	0	
40	Williamsport					250	550	S and G	G P	R	27 000 000, 12' deep	O		In day time only		
41	Wilkinsburg	[illegible]	30.8	20		450	900 to 1 300	S	P G	4 R	1, 9 500 000, 20 d'p, 1, 11 500 000, 21 d'p, 1, 5 000 000, 16 d'p, 1, 6 500 000, 17 d'p	O	Cons., 6 500 000 to 9 000 000	24	270 000 to 375 000	No
42	York	51.9	19.7	17	1	117	383	S	G	R	2 000 000, 16' deep	C	15%	12 to 24	208 000	No
	MARYLAND															
43	Baltimore	[illegible] to 97	24 to 26	9 (Feb. '99)		10	0 to 400	S	G P	S and R	2 S, 540 000; 2 R, 78 000 000, 20 deep	C O	S.—7 days; R., 2.2 days			
	OHIO															
44	Cleveland	[illegible]	10	10 (Feb., '99)	Water [illegible]	400	572 to 872	S	P	S and R	R, 80 000 000, 25 deep; R, 33 000 000, 21 deep; S, 390 000, 51 deep	O O C	114 000 000 cap. 72 000 000 cons.	24	2 000 000 to 3 000 000	1 000 000, 24 hrs.
45	Dayton	50	12				755	G	P					24	330 000	No, pressure kept to 60 lbs
46	Dennison	53	10	24 (Feb., '99)		400	850	S	G	R	4 000 000, 20 deep	O	3 days	24	100 000	No
47	Elyria							S	P					24	370 000	
48	Gallipolis							S	P	R	200 x 110 x 15	O	2 500 000	10	370 000	Yes

No.	City	Supply Main: Size of Main Either Gravity or Pumping (Inches)	If Supply is by Gravity, State Whether it is Variable or Practically Uniform	If Variable Give the Minimum Rate and Number of Hours	Character of Soil. (State whether Rock, Hard Pan, Clay, Sand, Gravel or Alluvial)	General Depth to Ground Water: In Route of Supply Main (Feet)	In Distribution System (Feet)	Depth to which Frost Extends in Streets: Average Depth (Feet)	Maximum Depth in Gravel (Feet)	Maximum Depth in Clay (Feet)	Maximum Depth in Sand (Feet)	Depth to which Frost Extends in Fields: Average Depth (Feet)	Maximum Depth in Gravel (Feet)	Maximum Depth in Clay (Feet)	Maximum Depth in Sand (Feet)	Average Snow Covering: In Streets	In Fields
1	Auburn	4 to 24	Slight	2 lbs. 6 A.M. to 8 A.M.	All	3	3	1	5¼	4	4½	1½	6			14"	2"
2	Bangor	24			All			2 to 7	4	3	4	2	4	1		2½'	2½'
3	Brewer	4 to 12						3 to 4	6	4	6	1½ to 2					
4	Rumford	16			Generally very coarse			4 to 5	7			1 to 4				1'	
5	Dover	16	Uniform		All	3	5	1	5							6"	
6	Manchester	30				4	4½	4½	5½	4	5½	4	4½	4½	5	6"	1
7	Nashua	16 and 24			S and G	Below mains			5		4	Good turf covering, 3 Light turf covering, 2				6"	1'
8	Billerica	12 and 16			R and G	5	5	4	4							6"	
9	Boston	20 to 48			Varies		Varies									Varies greatly	
10	Brookline	14 to 20			All	Below except for 3 000 ft	Below	[illegible]								Very little	1
11	Cambridge	40			C, S, G			2 to 4									
12	Fitchburg	16 to 30	Uniform		All	Varies	Mostly below	5	7							6" to 18"	[illegible]
13	Fall River	16 to 24			R, T, G				6	1	6						
14	Hyde Park	12 to 14			R, Hp, S, G			3	5¼							Very slight	
15	Lowell	30			R, S, G	None		4	4½		5					6"	
16	Lowell (Locks and Canals)	12 and 24	Variable	30 to 70 gals. per min.	Silt, Hp and Filling	Below except where canal water stands In some cases in canal under water		1½ to 3 More near canal walls								6" to 12"	6" to 18"
17	New Bedford	36 and 48			Very little clay, all others	Varies	Varies	2½ to 4	Here is where we have the trouble		Not very deep					Varies	
18	Reading	12			R, S, G				4½		4						
19	Sharon	6, 10, 12			All except C	4	Ab't 1½ miles under water in winter and spring	6" to 2"	4 to 6							Ab't 6"	
20	Springfield	24 and 30	Variable					3	5		4					3" to 8"	8" to 18"
21	Stoughton	12			All	Low	Low	4									
22	Westfield	14 to 20	Variable		S, G, A	[illegible]			5							2'	1'
23	Worcester	30 and 40	Uniform		All			1									
24	Bridgeport	16 to 30			Mixed and G	Deep	Deep	Max. 5				3 under turf				2"	1"
25	New London	24	Variable	850 gals. per min for short time	All	All	Usually below mains	[illegible]	5			1				[illegible]	
26	Norwich	10	Variable		All		Very little	2½ to 3	5½	3	5	1 to 2					
27	Rockville	6 to 20 G. 30 H S	Uniform		G	Below	In few places where mains are below river bed	2½ to 3	2½ to 3			2, to 4				6" to 12"	
28	Wallingford	8 to 12	Variable	438 000 in 24 hr. for 3 hrs.	Hp, S	6	10±	2		3	4					2 past [illegible] nothing	
29	Canandaigua	12 and 16			All	14	11	2		1	2½	1½				1"	
30	Woodhaven Water Supply Co. New York City	16			S	30	30 to 40	1½			4½					Very little	
31	Waterford	10			All	None	None	4		5	4½					None	
32	Yonkers	18 and 24			R, Hp, S, C	None	None	1									
33	Lewiston	2, 12; 1, 16; 1, 10	Uniform		R, C												
34	Mauch Chunk	9 to 30	Uniform		Mostly R	Along creeks											
35	Monessen	10 to 12	Variable	2 500 gals	C only	None	None	[illegible]		2		[illegible]					
36	Reading	10 to 36	Uniform		R, Hp, C, G	1 up	2 up			5							
37	Shamokin	14 to 18	Variable		Shale and Hp	2 to 3	2 to 3										
38	South Pittsburg	12 to 24			C, Hp, R	None					1						
39	Westmoreland Water Co. (Greensburg, Youngwood, Jeannette, Penn Manor, Irwin)	8 to 18	Variable	6 hrs.	Various	1 to 4; 6 to 8	Low points 3 to 4; High points 6 to 8			1 to 2		1					
40	Williamsport	16 to 24	Variable	Short heavy pulls caused by R. R.	All	4	5 to 15			2	1	1½				4" to 6"	1' to 2'
41	Wilkinsburg	30 to 42	Uniform		C and Shale	Varies	Varies			4							
42	York	20 to 24	Variable	27 000	All	25	30	1½		2		1				Very little	6" to 8"
43	Baltimore				All												
44	Cleveland	2 to 48			All	None	None										
45	Dayton	60			G, T, Hp	13	12									4"	
46	Dennison	12			[illegible]	11	11	1		3						Very little	
47	Elyria	20			C, R, S, G												
48	Gallipolis	2 to 12			S, G			1									

TABLE I.—Part II.

No.	City	Is Ground Likely to be Entirely Free from Snow during Days or Weeks of Coldest Weather?	If Depths are Changed in Soils of Different Character, Specify. (Feet.)	Depth to which Pipes are Laid: Depth to Axis of Pipe: Supply Mains: In Streets (Feet.)	Supply Mains: In Fields (Feet.)	Distribution System: In Streets (Feet.)	Distribution System: In Fields (Feet.)	Do You Take Into Account the Effect of Different Pavements in Streets?	Service Connections: Character (describe method of connecting with main, whether tapped on top or side)	Service Connections: Size (Inches)	Service Connections: Depth (Feet.)	Hydrant Branches: Size (Inches)	Hydrant Branches: Depth (Feet.)	Hydrant Branches: Average Length (Feet.)	Hydrants: State Method of Providing for Drainage	Number of Cases of Freezing Yearly: In Mains	Number of Cases of Freezing Yearly: In Services	Are the Depths of Pipe in Your Judgment generally Sufficient except under Extreme Conditions of Temperature?	Do These Unusual Conditions Occur with Sufficient Frequency to Justify a General Lowering of the Pipe System?
	Maine																		
1	Auburn	Yes	5 to 6	5	4			Yes	Side	1	6	6	5½	20	Sewerage, plug drip and pump out		3	Yes	No
2	Bangor	Yes		6					Side	½ to 4	6	4 to 6	7	7	Plugged	Not often	8 to 60	Yes	No
3	Brewer	Yes		6					Side	1	6	4 to 6	7	12	Plugged, pump out	0	4	Yes	No
4	Rumford	Yes		5 cover				No	Side	¾	5+	6	5	20	Nothing special required	0	10	Yes	No
	New Hampshire																		
5	Dover	Light covering		5½	5½	4½	4½	No	45°	1 to 4	4½	6	5	10	Bottom drainage	None this last winter	None this last winter	Yes, except in extreme cold weather. We had service pipe freeze in gravel 5' 9" under ground, winter 190[illegible]	No
6	Manchester	Yes		5½	4½			No	Side	¾	5½	6	5½	9	None	2	10	Yes	No
7	Nashua	No	4½ to 5 covering except in few cases where pipe is shallow. Does not freeze because of circulation	5½	5½	5	5	No	Side	¾ to 2	5	4 to 10	5	8	Loose brick chamber around waste	2	6	Yes	No
	Massachusetts																		
8	Billerica	Yes		4½ cover					Top	¾ to 1½	4½	6	4½	15	Small cobbles around foot of hydrant	0	0	Yes	No
9	Boston	Yes		3½ cover		5		No		¾ to 1½	5	6 to 8	5	10	Usually through ground	None for several years	This year to date, 2	Yes, under any conditions that have obtained since 1895	No
10	Brookline	Yes		4½ to 5½		4½ to 5½		Streets have been paved since pipe was laid	Side	1	5½	6	5	10	In clay soil, gravel or chipped stones around hydrant	1 in 34 years	2 in 34 years		
11	Cambridge			4 cover				No	Side	¾ to 2	4½	6	4 to 4½	18	Loose stone around waste			Yes	No
12	Fitchburg	Yes	4 to 5 of earth above pipe	7	5 to 6	7		No	Side	¾ to 8	6	4 to 6	6	25					
13	Fall River		4½ to 5. Deeper in gravel than in clay					No	Side	½ to 2	4½ to 5	6 to 8	4½ to 5	10	Plug and pump out in wet ground after using	Very few		Yes	No
14	Hyde Park	Yes	4½ cover with few exceptions	5 in some cases for short distance		4½ cover		No	Side	1	4½	6 nearly	4½	15	None but waste in hydrant	0	0	Yes	No
15	Lowell	Very rarely except in St. R. R. tracks	Vary according to grade. 7 to 30	5 trench				No	Side	¾ to 2	5	6	5	10	None, drains into ground. No trouble	[illegible] in last 20 years	50 in last 20 years	Yes, most cases have occurred where grade of street was lowered, leaving pipe shallow, i. e., less than 5' to bottom of pipe and during a long period of zero weather with little snow on ground	No
16	Lowell (Locks and Canals)	No	No	About 5 except in some cases 7		5½		No				6 to 8	5½ to 6	5 to 20	Leak hole with loose stone around hydrant	None, but occasionally some of old-style hydrants freeze		Yes	No
17	New Bedford	Yes		4 cover		4 cover		Large pipe do not need to be covered as much, but if laid with less covering would trespass upon location of gas pipes, electric conduits, etc. Pavements certainly help the frost from reaching a greater depth	Side	1½ to 2	1	4 to 6	4	8	Seldom have a frozen hydrant. Operate them late in fall and see that they properly drain. Do not open them during winter months unless absolutely necessary	Many years without a single case, then comes a cold snap and shortly have trouble with 3 or 4 dead ends	Several each year commence inside building and work out	Four feet is a good depth for this locality. I should not want to make it any less, and certainly should not advise greater depth	No
18	Reading	Yes		5		5		No	45°	¾ to 6	Cover 4½ to 5	6 to 8	Cover 4½			0	Very few	Yes	No
19	Sharon	Yes	5 to 4	5		4½		No	Side	¾ to 1	4 to 6	4 to 6	4½	14	Drip in bottom or side near bottom	0	5 in 23 years	Yes, some parts of system, i. e., around Lake Massapoag, are laid about 3' 6" to 3' 9" to axis of pipe, but during winter and spring are covered with water	No
20	Springfield	In streets Yes		About 5½. In places near surface				No	Side	¾ to 8	4½ to 5	4 to 8	5½	8	Drain into ground automatically. Base of hyd. surrounded by trap rock or screened gravel	0	1904, 51, 1905, 30, 1907, 19, 1908, 4	Yes	No
21	Stoughton	Yes	Varies from 3' 5" to 5' 5" to bottom of trench						Side form'ly on top	¾	3 to 5	4 to 6			Bottom drips	1	Many in 1903-4-5. Have been lowered since	Yes	No
22	Westfield	Yes				About 5½		No	Side	¾ to 1	4 to 6	4 to 6	4 to 5	12	Stone about drip	Very few		Yes	No
23	Worcester			4½ to center of pipe is usual depth				No	Side	¾ to 10	4½	4 to 10	4½	8 to 12	Hyd. set in gravel or filling of loose stones set around it	0	Very few	Yes	No
	Connecticut																		
24	Bridgeport	Yes	Many places entirely exposed in sizes 12" or larger, but unless under constant draft by gravity they are emptied	4 cover	1½ cover	4 cover	0	No	Side	¾ to 12	4 cover	4 to 8	4 cover	30	Some, drip connecting sewer. Some dry well around base	Not any last 2 years	Very few except inside cellars and houses poorly plumbed	They are, we lay all sizes in the city with 4' of cover and think this sufficient even in extremely cold weather long continued	No
25	New London	Yes	1 to 12 according to grade			4		Frost less deep under pavement	Top	¾ to 4	3 to 4	6	5	18 to 20	Broken stone near bottom	0	Seldom excepting in extreme cold years in gravel	Yes	No
26	Norwich	Yes		4	3	3½		Yes, about 6" extra depth	Part top Part 45°	¾ to 2	4½	4 to 6	3½	10	To sewer and culverts and surrounding hydrant bases with loose stone	Practically none except for more dead ends in some winters	Very few except when they begin to freeze in cold cellars	While experience so far as mere expense is concerned does not so indicate on account of occasional inconvenience and possibility of more, a depth of 4½' to axis is recommended	Not so far as pipes already laid are concerned
27	Rockville	Yes	20" main, 2½ to 3	4 cover				No paved streets. Macadam	Side	½	3½ to 4	6	4 cover	8 to 10	Cobbles	Only at long intervals	Occasionally	Yes	No
28	Wallingford	Yes		4	3	4		No pavement	Top	¾ to ¾	4	4	4	10	Stone around drip	None in past 2 years	None in past 2 years. Where 4' deep, except in sand, have had no trouble, but I find some in rock and other conditions 1½ to 2' that have frozen	Yes	No
	New York																		
29	Canandaigua	Yes		4½ cover				No	Top	¾ to 1	4	4 to 6	4½ cover	12	Hyd. packed at bottom with about 2 bbl. of stone	1 in 14 years	Very few	Yes	No
30	Woodhaven Water Supply Co. New York City	Yes		3½ trench				No	Top			4	3½ trench	4 to 6	Waste in sand	0	No record kept	Yes	No
31	Waterford	Yes				5 to 5½ 4 to 4½ in rock		We lay 6" lower under brick	Top and side	¾ to 6	4 to 5½	4 to 6	4 to 5½	25	Connect with sewer or drip made by ½ yd. cobble and brick	3 in 1903	Numerous	Yes, except where services are tapped on top of main	No
32	Yonkers	No		4½		4½		No	45°	¾ to 8	4	4	4	6	Blind drainage by stoning up	7 dead ends, 1903 4	No record	Yes	No
	Pennsylvania																		
33	Lewiston	No		4½ to 5		4		No	Side	⅝ and ¾	4 to 4½	4	4	14	Set on broken stone. Quantity depending on nature of ground		None for three years	Yes; we endeavor to have every main circulate by eliminating dead ends, and where we must have a dead end we provide a blow-off which we open during extreme cold weather	
34	Mauch Chunk		No	Merely covered		3 cover		No	Both	¾ to 2	3	4 to 6	3 cover	30	Automatic. We use Adams Patent Fire Hydrant, but occasionally have trouble in waste or drip clogging. Inspect carefully every hydrant in fall and put in good condition all hydrants	Have had none in over 20 years	4 cases in last 4 years	Yes, under the conditions of opening drain gates at low points and various ends or terminations of mains to cause a constant circulation during winter months. Some gates are used for flushing out mains, as in our judgment it seems necessary at any time after fall and spring rains	
35	Monessen	Yes		3 to 4 cover				No pavement	Side	¾ to 1	2½ to 3½	4	3	20	Set on top of ½ bushel of crushed stone	0	0	Yes	No
36	Reading	Yes	No	3 cover. Some pipes exposed for short dist.		4 to 4½	4 to 4½	No	Top	¾ to 8	3½	4 to 6	4	15	1 cu. yd. broken stone placed around barrel	2 in 10 years	None [illegible]	Yes	No
37	Shamokin			1½ to 3 cover		3 cover			Top	1		4 to 6	3 to 4	20 to 30			0	Yes, we have never had any mains freeze except in one or two cases where street was cut down and we neglected to lower pipe	
38	South Pittsburg	Yes	No	3½ cover					Top	¾ to 1	3	6	3½	12 to 36	Hydrant set in broken rock	0		Yes	
39	Westmoreland Water Co. (Greensburg, Youngwood, Jeannette, Penn Manor, Irwin)	Yes		3 cover		3½ cover		Yes	Both	1	4	4 to 6	3½ to 5	10	Hydrant broken stone surrounding	None except bare pipe on bridges	Seldom	Yes, no trouble with mains except on bridges and exposed places. 99% of frozen service pipes due to plumbers' "skinning" work, mostly at cellar wall	No
40	Williamsport	No		3 to 6	1	5 trench		No	Side	¾ to ¾	5	4 to 6	5	8 to 30	Fill in around drip with gravel 2'×2'×2'	Very rare		Yes	No
41	Wilkinsburg	Yes		3 to 10	1 to 30	4' to 10', 4½' trench, over 10', 3½ cover		No	45°	¾ to ¾	4½	4 to 6	4½ to 5	3 to 8	Sump below drip of hydrant filled with about ½ cu. yd. broken stone covered with tarred roofing paper to keep out clay	None except where street graded over main		Yes	
42	York	Yes		3 cover				No	Side	¾ up	3	4 to 6	3	20	None except drip	None	2 or 3	Yes, we do not lower our mains when grades are changed except where covering over pipe is reduced to less than 2½'	No
	Maryland																		
43	Baltimore			3½ cover				No		¾ to 2	3+	6 to 8	3+	20	Automatic drip draining into soil			Yes	No
	Ohio																		
44	Cleveland	Yes	No	5 to 5½		6.2 to 6.7	5.2 to 5.7	No	45°	¾ to 6	6 cover	4 to 6	6 cover	10 ±	Stone around base of hydrant	3, 4" in 1885, 1, 4" in 1904, none in other years	2,001 [illegible] 1904, None since	Yes	No
45	Dayton	Yes		4½ cover				No	Side	¾ to 8	5	4 to 6	4½	15	Waste through drip	None	None	Yes	No
46	Dennison	Yes		3½ cover				No	45°	¾	3½ cover	4 to 6	3½ cover	8	Tile drain to nearest sewer	None in 8 years	25 per year	Yes	No
47	Elyria	Yes		4½ to 5 cover				No	Top	¾	4	4 to 6	4½	20	Broken stone around bottom or connecting to sewer	None	None	Yes	
48	Gallipolis			4½				No	Top	¾ to 1½		6	4½	22	Drainage of bottom	None	None	Yes	No

TABLE I.—Part III.

No.	City	Temperatures, Degrees Fahr.: Mean Yearly Temperature	Mean Temperature Coldest Month	Extreme Minimum Temperature and Date of Occurrence	Minimum Temperature at Source of Supply and Date of Observation	Location of City: Distance from Ocean, Miles	Elevation above Sea Level	Source of Supply Surface or Ground Water	Method of Distribution Gravity or Pumping	Elevated Storage with Pumping System: Whether Reservoir or Standpipe	Size and Depth of Reservoir or Standpipe	Reservoir or Standpipe Open or Covered	Capacity of Reservoir or Standpipe in Relation to Daily Consumption	Hours of Pumping Daily in Period of Minimum Temperature	Approximate Hourly Rate of Pumping during Winter Months	Does Pumping Entirely Cease at Night during Coldest Weather? If Not, Give Minimum Hourly Pumping Rate	Supply Mains: Size of Main, Either Gravity or Pumping (Inches)	If Supply is by Gravity, State Whether It is Variable or Practically Uniform	If Variable Give the Minimum Rate and Number of Hours	Character of Soil. State whether Rock, Hard Pan, Clay, Sand, Gravel or Alluvial	General Depth of Ground Water: In Route of Supply Mains (Feet)	In Distribution System (Feet)	Depth to which Frost Extends in Streets: Average Depth (Feet)	Maximum Depth in Gravel (Feet)	Maximum Depth in Clay (Feet)	Maximum Depth in Sand (Feet)	Depth to which Frost Extends in Fields: Average Depth (Feet)	Maximum Depth in Gravel (Feet)	Maximum Depth in Clay (Feet)	Maximum Depth in Sand (Feet)	Average Snow Covering: In Streets (Inches)	In Fields (Inches)
	Ohio																															
49	Hamilton							G	G and P	R	3 000 000, 30' deep	O	Consumption 2 500 000		8	Yes	10 to 20			All	2½ to 3	2½ to 3		3							Very little	
50	Jackson						665	G	G	S	30 x 50	O		16	22	No	16	Variable		R Hp C A	3½	4	1½				1¼					
51	Loraine	50.4	18	−10 (Feb.)		475	605	S	P					24	125 000	No	12 to 24			C		2			1							
52	Marietta					500	607	S	P	2 R 2 S	1 272 334 60 x 30	O	Consumption 2 300 000	20	0.582	5 hours at night	12			S A	20	20	1½								8	
53	New Philadelphia			21				G	P	R	2 000 000	O	2 times	12	18	Yes	12	Uniform		G S			2 to 3	2 to 3		2 to (	1½ to 2	1½ to 2		1½ to 2	2	5
54	Lima	51.6	19.4	20.5 (Feb., '99)		700		S	P	R	Storage, 400 000 000 Dist., 120 000 000	O	Consumption 3 000 000	21	125 000	25 000	20			I	25	25	3½		5½		3½		5½			
55	Oberlin	40.1	25.8	−21 (Jan., '94)		500	810	S	P	S	18 x 35	C	1 to 3	0	35 000	Yes	12			C	None	None		None	2½	None			½		Little	
56	Springfield	56	0	−20 (Feb., '99)	30	750	700	G	P	S	30 x 120	O	502 000	22	154 200	2 hours	24	Variable		R C G	None	None	2	3	3½		3	3	3½		4	4
57	Warren	50.6		−11 (Feb.)			885	G	P	S	22 x 140	O	¼	20	45 000	Yes	16			C	None	None	2 to 3		2 to 3		1				3	6 to 8
	Indiana																															
58	East Chicago					1700		S	P	S	16 x 100	O		24	24	No	16			S	0 to 6	0 to 6	3½ to 4			5½					3	
	Illinois																															
59	Belleville					1000	531	G	P	S	25 x 120	C	½	16	50 000	Yes	12 to 20			C	Below	Below										
60	Elgin			−15		985	737	S G	P					24		No	16 to 24						2 to 6	3½			1½ to 5	5½	3 to 4	3 to 4	Very little	
61	Mattoon	55.3	36.4	−32	−32		725	G	P G	S R	R, 150 000 S, 15 x 120	C	10 times			Yes	12			A	2 to 6	2 to 6	3½								0	0
62	Peoria	50	25.1	−22 (1899)		900	440 to 750	G	P	R	20 to 38' deep	O	4½ times	20 to 24	150 000 100 000	Yes	30	Variable	25 50 000	C S G			2½	4	2	4					10	12
63	Quincy	55	20.5	−22 (Feb.)		750	350	S	P	R	330 x 420 x 26	O	10 days	7½	200 000	Yes	20			C R	15 to 40		1			2½		1½		3	2	
	Wisconsin																															
64	Ashland	40	6.2		−32 (Jan., '04)	1000	602 to 690	S	P	O				24	550 000	No	12 to 20			C			5		7		2				6 to 10	2' 6"
65	Milwaukee	43	33.3	−18 (Feb., '05)	35	1000	501 to 750	S	P	R S	R, 21 000 000, 20' deep S, 4' diameter	O C	Reservoir, 20 000 000 Consumption, 20 000 000	24	24	No	7½	Supply tunnel under lake		C	4		4½	6	3½	6					6	
	Michigan																															
66	Ann Arbor			−6	−6	800	850	G	G	R	250 x 100 x 17	O	3 000 000	24	24	No	12 to 16	Uniform		G C	30 to 70		3	3	3	3	1	1	1	1	6	6
67	Grand Rapids	48.1	23.8	−24 (Feb., '99)			585	S	P	R, H S S, L S	R, 5 000 000 S, 75 x 30 T, 60 x 30	R S, O T, C	13 500 000	24	13 500 000 24 hr.	No	12 to 30			All												
68	Ludington							S	P					24	24	25 000	8 to 16			S		5 to 15				3½	4			10"	1'	2 to 6
	Iowa																															
69	Burlington	51.2	23.7	−27 (Feb., '05)		1100	525 to 675	S	P					24	75 800	No	12 to 16			C	Below	Below	2½		4 to 5				3½			
70	Centerville	50	24.5	−5		1200	1000	G	P	S R	R, 10 x 60 S, 12 x 100	C	R, 3½ days S, 1½ days	2	28 000	Yes	4 to 6	Variable	12 hours at 13 000 per hour	C	15 to 30	16 to 30	1½ to 2									
71	Mason City			−34 (Feb., '05)			1350	G	P	R	180 x 34 x 20	C	500 000 gallons capacity 400 000 gallons consumpt'n	24	24		16			C R	4		4½		4							
72	Muscatine	49.4	22.6	17 (Feb., '91)	−32 (Jan., '84)	1200	538	G	P	R	250 x 20 x 20	O	2 000 000	10	10	12 hours	16			C S Hp	3	1 to 2	3	4	2 to 4	3 to 4½	3	4	2 to 4	3 to 4½	2 to 6	4" to 1'
	Wyoming																															
73	Green River and Rock Springs supplying several towns, Inc. Union Pacific Water Co.			−40 to 45 (Jan. or Feb.)		1100	6280	S	P G	R		O	Green River 2 days	U P W Co., as required; Green R, 24	30 000	U P W Co., Yes Green River, No	8 to 12	Uniform		R G C	None	None	4½				4½				Very little	
	Washington																															
74	Everett	51.5	39	0	0	Ocean	100	G	P	R	14' 8" deep 1 225 000 gal	O	2 020 000 gallons	15	100 000	Yes	22			C S Hp	2	8	1	1	1	1	6"	6"	6"	6"	2	2
75	Hoquiam	40 to 60		10 (Jan., '09)		16	0	S	P	2 R	4 500 000, 21' deep	O	2 days	20 24		No	10 to 14			A C	0	1	6"	3"	1	3	Slight				Very little	
	Canada																															
76	Charlottetown, P. E. I.	42				Ocean	10 to 50	G	P G	R	1 250 000	C	2	8	85 000	Yes	14	Uniform		C R			4		3½		4		4½		2	2
77	Yarmouth, N. S.	44	25			1½	65	S	P G	R	175' 6" x 125' 5" x 18'	O		23		No	12	Variable		R C G			1½	2	2	2	1				2	
78	Montreal, P. Q.	42	12				50 to 175	S	P	R		O	1 day	24	3 000 000	No	2, 30 3, 24			Variable			4½ to 5	7	5		1½	2	1½	1½	3'	3'
79	Brantford, Ont.	50						G	P					24	2 500 000 daily	No	10 to 14			S G	6	5½	2 to 4	6		6	1				1' to 1½'	1 to 1½
80	Kingston, Ont.	44.6	19.1	−16		300	285	S	P	S	40 x 80	C	628 000 capacity 2 300 000 consumption				16			R C	7	7	4½		3½						1'	
81	London, Ont.	46.3	23.1	−20 (Feb., '08)	−20	580	810	G	P	R	230 x 230 x 13.5	O	36 hours	24	158 300	No	18	Variable		Hp S G C	25 to 30	15	4	4½	4½	4	2½	3½	4	4'	9	1½'
82	Pembroke, Ont.					1000	380 to 490	S	P	S	60 x 20	O	1	15	25 000	Yes	8			All except R			4	6	5	4	3				15	24'
83	St. Catherines, Ont.			18 (1904-5)	−18	450	309	S	G				1 92 000 000 2 750 000				16 to 20	Variable	30% less during night	All	0 to 170	0 to 16	3	5	2½	7 to 8	3	None	1	3	4	4
84	Winnipeg, Man.	35	13		−53.5 (Dec., '79)	1600	756	G	P	R	6 000 000	C	1½ times	24	6 000 000 24 hrs		12 to 20			C			7		8		6 to 8		9		1 to 1½	1½
85	Regina, Sask.		−20	−50 (Feb.)	50 (Feb.)	1200	1885	G	P	R	1 100 000	C	50% greater	24	20	No	10	Uniform		G C	12	None	5 to 6		5 to 6		4		5		6	6
86	Edmonton, Alta.	37	8	30 (Dec., '08)	−36	900	2240	G	P					24	85 000	75 000	12			C	None	None	4 to 8		8				4		4	10
	New York																															
87	Rochester	47.25	24.1	−14 (Jan., '04)	−8 (Feb., '08)	250	510	S	G, P	R	142 000 000 25' deep 22 500 000 10' deep	O	10	24	1 000 000	No 500 000 ±	20 24, 33	Uniform		Varies, generally S	0 to 50	20	2 to 3				1½				8	1'

TABLE 1. — PART IV.

		Is Ground Likely to be Entirely Free from Snow during Days or Weeks of Coldest Weather?	If Depths are Changed in Soils of Different Character, Specify	Depth to which Pipes are Laid: Depth to Axis of Pipe: Supply Mains: In Streets	Supply Mains: In Fields	Distribution System: In Streets	Distribution System: In Fields	Do You Take into Account the Effect of Different Pavement in Streets?	Service Connections: Character (describe method of connecting with main, whether tapped on top or side)	Service Connections: Size	Service Connections: Depth	Hydrant Branches: Size	Hydrant Branches: Depth	Hydrant Branches: Average Length	Hydrants: State method of providing for drainage	Number of Cases of Freezing Yearly: In Mains	Number of Cases of Freezing Yearly: In Services	Are the Depths of Pipe in Your Judgment generally Sufficient except under Extreme Conditions of Temperature?	Do These Unusual Conditions Occur with Sufficient Frequency to Justify a General Lowering of the Pipe System?
	OHIO																		
49	Hamilton			5'					Top	Less than 1"	4'-5'			25		0	0	Yes	No
50	Jackson	Yes	No					No	Top	½"-¾"		6"	4½'	12'	Crushed stone	0	0	More than sufficient	No
51	Lorain			5'				No	Side	½"-¾"		6"	5'	12'-14'	Loose stone	0	196	Yes	No
52	Marietta	No		4½'		3'		No	Top	½"-1"	2½'-3'	4"-6"	3'-4'	12'	Bowlders placed around bottom	0	Only in residences	Yes	No
53	New Philadelphia	Yes		4'	4'	4'	4'	No	Top	¾"-1"	4'	6"	4'	12'	Gravelly soil No trouble	0	6	Yes	No
54	Lima	No		5' 10"	6'	5' 10"	6'	No	Top	½"-6"	4'	6"	5'	10'	Pump out after using	None	None	Never had any freezing	No
55	Oberlin	Yes				5' cover		No		¾"	4'	4"	6'	15'	Broken stone around drip				
56	Springfield	Yes			4' cover	4' cover		No		½"-1"	4'	6"	4'	12'		1	Only in houses	Yes	No
57	Warren	Yes			5' trench	5' trench		No	Side	½"-¾"	3'-4½'	6"	5'	11'	½ bushel stone or brick	0	Generally none 3 or 4 4 years ago	Yes	No
	INDIANA																		
58	East Chicago	Yes		2'-4'		3½'		No	Side	¾"	3'-4'	4"-6"	3'-4'	12'	Drip	None since winter, 1903	Several, but becoming less each year	Yes	No
	ILLINOIS																		
59	Belleville				3' cover			Yes	Top	¾"	3' cover	4"-6"	3' cover	8'	Brick bats, crushed rock	One in 8 years	10 in 8 years	Yes	No
60	Elgin	Yes			6' cover			No	Side	¾"-1½"	6'-7'	6"	6' 6"	12'	Drain a few	0	0 in 10 years		No
61	Mattoon	Yes			3' cover			No	45°	¾"-¾"	3'	4"	3' 6"	12'	Broken brick or crushed stone	0	0	Yes	No
62	Peoria	Yes			5' cover			No	45°		5'	4"-10"	5'	7'-15'	Base of hydrant set on stone or brick. 2 cu. ft. brick bats or broken stone	None in 10 years except March, 1899	0	The pipes which froze had 3' to 4' cover, which is hardly enough or dead ends Five feet I think, is more than enough, and cover has recently been specified as 4½' for further extensions.	No
63	Quincy	Yes			4½' cover			No	45°	¾"-1"	4½'	6"	4½'	14'	Stone or gravel around waste holes	0	0	Yes	
	WISCONSIN																		
64	Ashland	No			6' cover			No	Side	¾"-2"	6'	4"	6'	16'	Hydrant plugged and hydrant pumped dry on account of surface water collecting in trenches	0	5	Yes	No
65	Milwaukee	Yes		6' 0"		6'		No	Side	¾"-2"	6' 6"	6"	6'	10'	Connect with sewer	0	0	Yes	No
	MICHIGAN																		
66	Ann Arbor	Yes		5'	5'			No	Top	¾"-4"	6'	6"-8"	6'	12'	Cast-iron drip box	0	0	Yes	
67	Grand Rapids	Yes		5' 9"		5' 9"					6' in streets 5' in lawns	6"	7½'	10'-18'				Old mains laid in trench 4' to 5' deep, which did not prove sufficient.	We are lowering mains except large ones to at least 5' cover as streets are being re-improved.
68	Ludington	Yes			4' cover			No	Side	½"-3"	4'	4"	4'	10'	Connect with sewer where possible. Pit filled with broken stone where no sewer	0		Yes Eight years ago temperature dropped to 40° below zero for two weeks. Frost went below mains on paved streets. First time in twenty-five years this has occurred.	No With our sand, frost will not penetrate the ground for depth except under a paved or hard-packed street. The flow of water is sufficient to keep mains clear.
	IOWA																		
69	Burlington	Yes			5' 6" cover			No	Side			4"-6"	5' 6" cover	14'	Pump out in fall and after fires in winter	0	Few cases, 1903, '04, '05. Since then very few	Yes In a few cases we found city had changed the grade of streets before laying brick pavements, leaving the mains with only 3' 6" or 4' cover for short distances. Have had no trouble with mains in such place, but hydrant and services in these shallow places have been frozen.	Our judgment is that in this city we should have not less than 5' cover over services and hydrant branches.
70	Centerville	Yes			4.5 ft.				Top	¾"-2"	4'	4"	4.5'	7'-10'	Drip. No connection to sewer or other drain	0	None in streets. All cases in houses or near surface of ground	Yes Have had some mains but 12" to 15" underground where streets were graded. These did not freeze last winter, 1907.	No
71	Mason City	Yes			6' trench			No	Side	¾"-1"	6'	4"	6'	8'	If dirt soil, we use stone around hydrant for drainage	None except in 1905		Yes	No
72	Muscatine	Yes		6'				No	Both	¾"-6"	6'	6"	6'	7'	By rock with cover of straw	6	In extreme winters, 25	Yes	No
	WYOMING																		
73	Green River and Rock Springs supplying several towns, inc. Union Pacific Water Co.	Entire winter			5' cover			No	Top	½"-¾"		4"		40'	Medium sized rock	None in recent years		Yes	No
	WASHINGTON																		
74	Everett	Yes		3'	2'	2' 10"	2' 10"	No	45°	½"-2"	2'	4"-8"	2' 10"	10'	Coarse gravel	0	0	Yes	No
75	Hoquiam	Yes		3'		2½'		Yes	Top	½"-1"	1½'	6"	2½'	20'	Gravel and stone around base	0	Many in exposed places with no covering	Yes	No
	CANADA																		
76	Charlottetown, P. E. I.	Yes			5' cover			No pavement	Side	½"-1"	5'	6"	5'	20'	No drainage required on account of nature of soil	0	0	Yes	No
77	Yarmouth, N. S.	Yes		4'				No	Side	½"-¾"	3' 5"	6"	4'	10'	Sewers when convenient. No sewers, plug drip and pump	0	2 in 10 years	Yes	
78	Montreal, Que.	No		4' 9"-5'		6' trench		No	Top	½"-1"	6'	4"-8"	6'	6'-8'	Drip drains to street sewer	Very few	300 to 400 every winter	Yes. Most frozen services occur in severe winters when the ground surface is denuded of snow, and it is generally found that the pipes have not the regulation depth of 6', due generally to change of grade for street pavement, perhaps long after services were laid.	I should say not. I believe if all our services were laid to 6' depth there would be very few cases of freezing. I would not advise laying them at a lesser depth in our climate
79	Brantford, Ont.	Yes	In gravel deeper In clay not so deep	12"-18"		5½' cover		No	Both	¾"	5½' cover	6"	5½' cover		Vent hole at foot and all put in with pit gravel at bottom	0	0		
80	Kingston, Ont.	Yes	Pipes laid 6" deeper where excavation is all rock	5'		5'		No pavement	Side	¾"-1"	5'-5½'	6"	5'-6'	12'	3" old boiler tube to sewers	0	Average, 10 for 20 years	Yes, for our conditions, 75% of pipes are in rock excavation. To put them deeper would increase cost much more than earth excavation and would interfere with sewers, which average 6' 6" deep.	If a main freezes at any time it should be put deeper
81	London, Ont.	No	No		5' cover			No	Top	½"	5½'	6"	5' cover	12'	Protected by stone and gravel placed around bottom of hydrant	0	0	Yes	No
82	Pembroke, Ont.	No		5½'		5' 9"		No	Both	½"-1"	6'	4"-6"	5½'	6'	Connect to sewers or surface drains, also by seepage	None since 1893	Practically none, 1 in 1008	There has never been a case of either supply mains or distribution mains freezing. Services have occasionally frozen when no snow was on roadway and temperature about 35° below	No
83	St. Catharines, Ont.	Yes			5' cover			No	Both		6'	6"	5' cover	25'	In gravel, none. In clay, drain to sewer. Where no sewer, drips are plugged and hydrant pumped when used.	None since 1903	None except in severe winter, 1904-05	Yes	No
84	Winnipeg, Man.	Yes		6' 10"		6' 10"		No	Side	¾"		6"-8"	8'	23'	Drip connection with sewer			Sufficient in all cases where there is circulation. Dead ends only freeze	No
85	Regina, Saskatchewan	Yes		8'		8'	8'	No	Side	¾"-2"	7½'	6"	7½'	4'	Tile drain to sewer	0	2%	Yes	No
86	Edmonton, Alberta	Yes			8' cover			No	45°	½"-2"	7½'-8'	6"	8'	30'	Drain to sewer	1	During the winter months 154 house services were frozen. The greater percentage of these were on the property where the 8' depth is not always adhered to. I should say that about 4 to 6 were frozen outside the street line, mainly caused by freezing of service casing and thence working into pipe. I have also found occasions where pipes froze on the property and the frost worked back into street pipes	Yes	No
	NEW YORK																		
87	Rochester, N. Y.	Yes	No	5'-6'		5'-8'			Side	½"-2"	1½' cover	4"-8"	4½'	7'	3" tile to sewer	0	Ordinary years, 5; 1902-3, 100± In very few cases is a service ever found frozen which has been laid properly at our stated depth of 4½' cover. This explanation must be made, however, that there are always a number of services frozen every year in the basements or cellars of houses where proper precautions are not taken, and the freezing process extends out through the cellar wall into the service in the above-mentioned statistics of frozen services		

at which the pipes should be laid. In 10 per cent. of the it appears that some attention is paid to the character of the surface, although apparently there is no prevailing rule. consider that a pavement is equal to one foot of cover; others ipe should be laid deeper in a paved street. An average of ies received indicates that freezing extends one foot deeper s than in fields; also that in streets frost will reach 1 foot s deeper in gravel than in clay, with sand half way be- en. In fields it would appear that frost will extend one foot ther in gravel than in clay, with sand again intermediate in ect. It is obvious that the character of the soil is a factor of h relative importance as to demand consideration in deter- ining the economical depth.

Fifty-three places report actual experience in the freezing of ipes. All of these cases were in distribution systems and none in e leading mains. Fifty per cent. were on dead ends and all re in pipes where there was little or no velocity. All but three the cases of freezing were in pipes smaller than 10 inches in ameter, only seven in pipes as large as 8 inches in diameter; in cases the ground was frozen below the axis of the pipe, and the ound water level was also below the pipe. In 80 per cent. of e cases the ground was bare of snow at the time of freezing. All ppages were total. Thirty-five places report the character of arth in which the pipes were laid; of these, 40 per cent. were in 48.6 per cent. in gravel, 5.7 per cent. in sand, and 5.7 per c . in rock.

ble 3 shows the latitude, average yearly and minimum temperatures (based on the United States Government Reports) of the places from which replies were received and also the depths at which the pipe was laid in these places. Obviously the temperature depends on other factors than latitude, and, believing that the mean temperature of the coldest month would provide a more satisfactory basis of comparison, a diagram, Fig. 1, with this temperature as the scale of the horizontal coördinate, and the depth, as reported, as the vertical coördinate, has been prepared. On this diagram the different places, from which replies were received, have been plotted. There is much variation in the relation of depth to temperature of coldest month, as indicated by the practice

TABLE 3.

Table of Cities and Towns, arranged in Order of their Latitude, giving Average Yearly and Minimum Temperature, based upon United States Government Reports, and Depth to Center of Pipe in Distribution System.

	Lat. Approx.	Temperature.		Depth to Center of Pipe.
		Av. Yearly.	Minimum. Extreme.	
Edmonton, Alberta	53.5	37.0±	—30±	*8.0
Regina, Saskatchewan	50.5	36.0±	—50±	*7.5
Winnepeg, Man.	50.0	36.0±	—53.5±	7–8
Everett, Wash.	48.0	52.0±	24±	2.83
Hoquiam, Wash.	47.0	51.0±	18±	2.5
Ashland, Wis.	46.5	40.0±	—32±	*6.0
Charlottetown, P. E. I.	46.2	42.0±	.....	*5.0
Pembroke, Ont.	45.8	....	.....	5.75
Montreal, P. Q.	45.5	42.0±	.....	†6.0
Bangor, Me.	44.8	43.6±	—21±	6.0
Brewer, Me.	44.8	43.6±	—21±	6.0
Rumford, Me.	44.5	43.1	—17	*5.0
Belfast, Me.	44.4	43.6±	—21±	6.0
Kingston, Ont.	44.2	44.6±	—19±	5.0
Auburn, Me.	44.1	45.0±	—11±	4–5
Ludington, Mich.	44.0	46.0±	—10	*4.0
Yarmouth, N. S.	43.6	44.0±	.....	4.0
Rochester, N. Y.	43.2	48.6	—3	4.75–8.0
Mason City, Ia.	43.2	47.4	—13	6.0
Brantford, Ont.	43.1	50.0±	.....	*5.5
St. Catherines, Ont.	43.1	...	—18±	*5.0
Dover, N. H	43.1	46.0±	—10±	4.5
Manchester, N. H.	43.0	46.0±	—10±	4.5–5.5
Milwaukee, Wis.	43.0	47.9	—1	*6.0
Grand Rapids, Mich.	43.0	48.7	—6	5.75
London, Ont.	43.0	46.3±	—20±	*5.0
Canandaigua, N. Y.	42.9	49.0±	—3±	*4.5
Waterford, N. Y.	42.8	49.0±	—10±	5–5.5
Nashua, N. H.	42.8	47.7	—8	5.0
Billerica, Mass.	42.6	50.0±	—3±	*4.5
Fitchburg, Mass.	42.6	47.9	—5	*4–5
Lowell, Mass.	42.6	49.6	—3±	†5.0
Lowell (locks and canals), Mass.	42.6	....	.....	5.5
Reading, Mass.	42.6	50.0±	—3±	5.0
Ann Arbor, Mich.	42.5	49.1	—4	5.0
Boston, Mass.	42.4	50.0	—1	5.0
Brookline, Mass.	42.3	50.0±	—1±	4.5–5
Cambridge, Mass.	42.3	50.0±	—1±	*4.0
Hyde Park, Mass.	42.2	50.0±	—1±	*4.5
Worcester, Mass.	42.2	49.0	—4	4.5
Sharon, Mass	42.1	48.0±	—5±	5.0
Springfield, Mass.	42.1	51.6	—5±	5.5
Stoughton, Mass.	42.1	49.0±	—5±	†3.5–5.5

* Depth to top of pipe. † Depth of trench.

TABLE 3. — Continued.

	Lat. Approx.	Temperature.		Depth to Center of Pipe.
		Av. Yearly	Minimum. Extreme.	
Westfield, Mass.	42.1	52.0 ±	—5 ±	5.5
Elgin, Ill.	42.0	48.5 ±	—1 ±	*6.0
Rockville, Conn.	41.8	49.0 ±	—2	*4.0
Fall River, Mass.	41.7	49.4	1	4.5–5
New Bedford, Mass.	41.6	49.5 ±	3	*4.0
East Chicago, Ind.	41.6	51.0 ±	6 ±	3.5
Rock Springs, Wyo.	41.5	42.2	—21	*5.0
Norwich, Conn.	41.5	51.0 ±	2	3.5
Wallingford, Conn.	41.5	51.0	2	4.0
Cleveland, Ohio	41.5	50.0	1	5.2–5.7
Lorain, Ohio	41.5	50.3	12	5.0
Muscatine, Ia.	41.5	50.9 ±	0 ±	6.0
Elyria, Ohio	41.4	50.0 ±	1 ±	*4.5–5
Oberlin, Ohio	41.3	50.6	12	*5.0
New London, Conn.	41.3	50.7	2	4.0
Bridgeport, Conn.	41.2	51.5	2	*4.0
Williamsport, Penn.	41.2	51.2	1	†5.0
Warren, Ohio	41.2	50.0	10	†5.0
Yonkers, N. Y.	41.0	53.0 ±	5 ±	4–4.5
Mauch Chunk, Penn.	40.8	51.0	—5	3.0
Shamokin, Penn.	40.8	49.0 ±	—17 ±	*3.0
Woodhaven Water Company, N. Y.	40.7	53.3	5	†3.5
Peoria, Ill.	40.7	51.1	2	*5.0
Burlington, Ia.	40.7	51.5	—3	*5.5
Centerville, Ia.	40.7	49.5 ±	—9 ±	4.5
Lima, Ohio	40.7	51.4	—4	5.83
Lewiston, Penn.	40.5	51.0 ±	—5 ±	4.0
South Pittsburg, Penn.	40.5	52.8	—3	*3.5
Wilkinsburg, Penn. (Penn W. Co.)	40.5	52.8	—3	*3.5–4.5
Denison, Ohio	40.5	52.0 ±	—6 ±	*3.5
New Philadelphia, Penn.	40.5	50.5 ±	—7 ±	4.0
Reading, Penn.	40.4	53.6	4	4–4.75
Westmoreland County, Penn.	40.3	52.8 ±	—3 ±	*3.5
York, Penn.	40.0	53.0 ±	1 ±	*3.0
Springfield, Ohio	40.0	51.5 ±	—6 ±	*4.0
Quincy, Ill.	40.0	53.0	0	4.5
Dayton, Ohio	39.6	53.0	—7	*4.5
Marietta, Ohio	39.5	55.2	0	3.0
Mattoon, Ill.	39.5	53.5 ±	—11	*3.0
Hamilton, Ohio	39.4	54.0 ±	—3 ±	5
Baltimore, Md.	39.2	56.0	8	*3.5
Gallipolis, Ohio	38.9	57.0 ±	—4 ±	4.5
Belleville, Ill.	38.5	55.5 ±	5	*3.0

* Depth to top of pipe. † Depth of trench.

in different cities and towns. Presumably this is explainable in most cases by peculiar local conditions; in others, perhaps, by an illogical adaptation of depth to the requirements.

On this diagram a line has been drawn which expresses the relation of depth to mean temperature of coldest month as indicated by an average of the replies received. It will serve to emphasize the variation in depth in cities and towns with the same mean temperature of coldest month, which in the extreme is illustrated by Mauch Chunk, Pa., and Cleveland, Ohio, the former satisfactorily operating pipes at a depth to axis of 3 feet 6 inches, and the latter believing 6 feet 6 inches to be necessary. Obviously local conditions other than temperature, and including depth of snow covering, must furnish, in great part, the explanation. In connection with this diagram, a map, Fig. 2, has been prepared showing the lines of mean temperature of coldest month in the United States.

By reference to Tables 1 and 2 the places represented by the numbers on Fig. 1 can be ascertained. It will be noted that there is quite a marked grouping according to the depth used for pipe of cities and towns located geographically close to one another. The lesser depths employed in those places which appear below the average line are not explained by the use of ground water supplies, as there are as many ground water supplies above the average line as below. Those using shallow depths report practically no trouble, and the question remains whether this immunity results from peculiar local conditions or whether the general practice is unduly conservative. As already stated, it would seem that where there is any velocity of current, depths somewhat less than those indicated by this average line will generally prove sufficient to prevent freezing.

While all cases of freezing reported are stated to have resulted in total stoppage of the pipes, there are records of ice formation in concentric rings in pipes as large as 24 inches in diameter, the occurrences not being evidenced by stoppage of the large main, but only by loss of head through increased friction, or, in some cases, by stoppage of gates or smaller pipe connections by the ice loosening and breaking up in a thaw and forming an ice jam at some point of obstruction. Such formation of ice in a

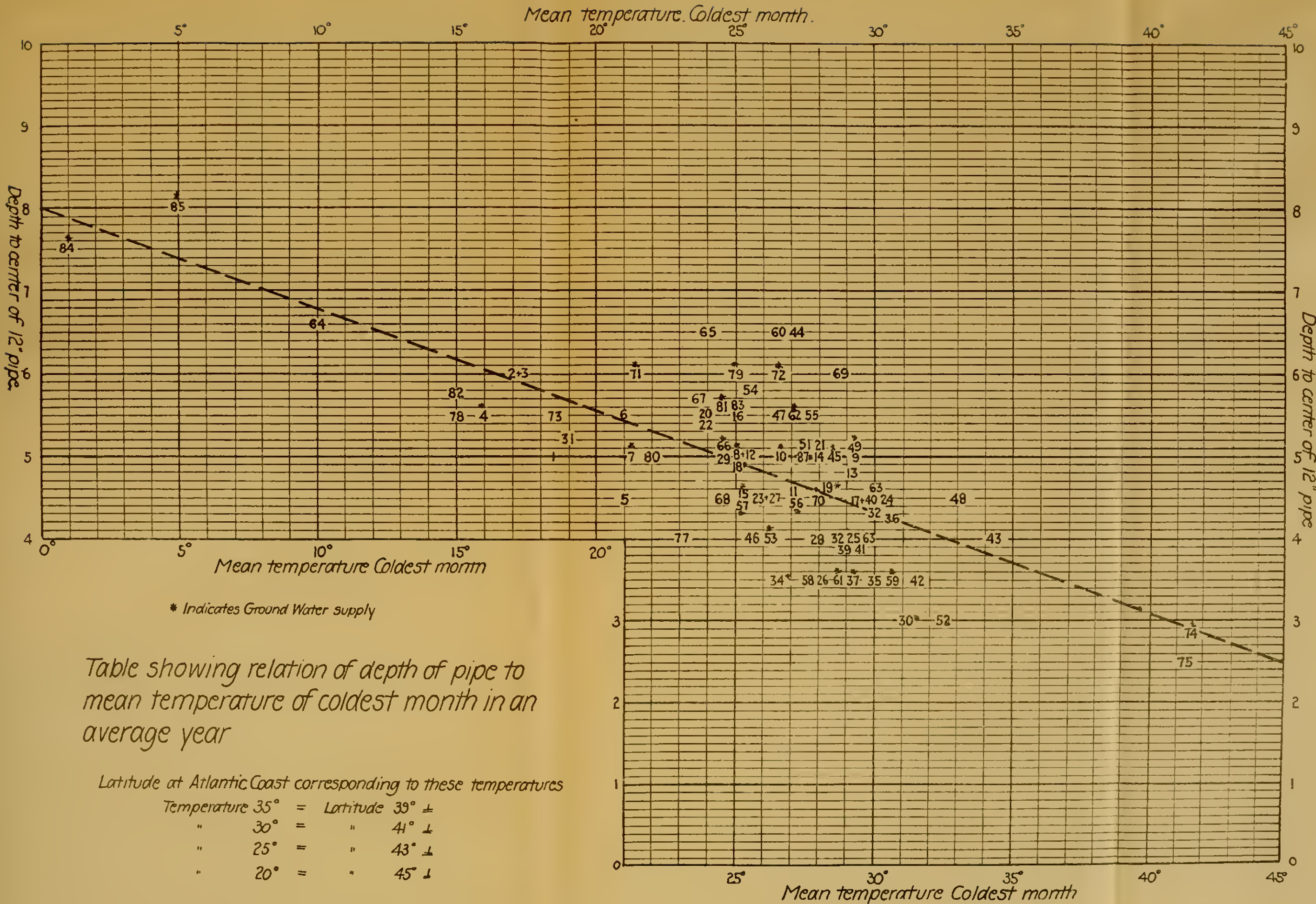

Mean temperature. Coldest month.
Depth to center of 12" pipe.
Mean temperature Coldest month
* Indicates Ground Water supply
Table showing relation of depth of pipe to mean temperature of coldest month in an average year
Latitude at Atlantic Coast corresponding to these temperatures
Temperature 35° = Latitude 39° ±
" 30° = " 41° ±
" 25° = " 43° ±
" 20° = " 45° ±

Fig. 1.


Map showing
LOCATION OF CITIES AND TOWNS
from which returns have been received.
Dotted contours indicate mean temperature of coldest month
in an average year plotted from U.S Government records
WASH.
ORE.
CAL.
NEV.
IDAHO
MONT.
WYO.
UTAH
ARIZ.
COLO.
NEW MEX.
N. DA.
S. DA.
NEB
KAN.
OKLA.
TEXAS
MINN.
IOWA
MO.
ARK.
LA.
WISC.
ILL.
MICH.
IND
OHIO
KY.
TENN.
MISS
ALA.
GA.
FLA.
S.C.
N.C.
VA.
W.VA.
MD.
PENN.
N.Y.
VT.
ME.
48°
44°
40°
36°
48° Lat.
44° Lat.
40° Lat.
36° Lat.

Fig. 2.

layer adjoining the metal of the pipe has occurred in instances of extreme low temperature in the eastern Canadian Provinces in conduits where there was a considerable velocity. Obviously, as the ring of ice forms, the velocity of the water increases and a total stoppage does not result. In other cases of freezing, particularly in smaller pipes, the ice formation is not solid nor does it start from the outside, but is rather in the form of "slush" uniformly distributed throughout the cross-section of the pipe. This has been noted in a 4-inch pipe, in which there was considerable velocity, laid at a depth of 6 feet in a salt marsh in New Brunswick.

There is a belief or tradition in the minds of many plumbers and water-works superintendents that most stoppages by ice formation occur in a thaw which follows a period of severe cold weather, and the reason generally advanced for this alleged phenomenon is that the evaporation from the surface during the early stages of the thaw produces additional refrigeration or reduction of temperature at the depth of the water main sufficient to cause freezing. No indication of the existence of such conditions has appeared in the reports received of frozen pipes, and this reference is here made to induce the production of evidence, if any exists, in support of this theory.

Your committee regrets that the lack of comprehensive response to the circular has made impossible the collection of data sufficient for a more definite and conclusive report.

Yours respectfully,

F. A. BARBOUR, *Chairman.*
W. C. HAWLEY.
W. C. HOAD.
EMIL KUICHLING.
R. S. LEA.
DABNEY H. MAURY.
R. WINTHROP PRATT.

JULY 19, 1909.

APPENDIX.

(Circular Letter.)

NEW ENGLAND WATER WORKS ASSOCIATION.

Boston, Mass., December 30, 1908

Dear Sir: — The undersigned were appointed a committee at the last annual convention of the New England Water Works Association to gather statistics relating to the depth at which water pipes are laid and the resulting experience in freezing. The subject of investigation is important in the possibility that under many conditions pipes are now laid at unnecessary depth.

How valuable the result of the investigation will be depends largely on the response of the men in charge of water-works systems throughout the country, to whom this circular is addressed.

The information desired is of two classes: First, data as to practice in the several cities and towns in the laying of pipes, and a general statement of the conditions which have a controlling influence on freezing. This information will probably be generally negative in character as regards freezing and will prove that, when laid at certain depths, pipes will not freeze. The other class of information is testimony as to experience in actual cases of freezing, with a statement of the controlling conditions. These latter include the size of pipe, depth, character of soil, temperature of air and water, and, last but not least, the velocity of flow in the pipe at the time of freezing.

The committee realize that in order to obtain such information it is necessary to seriously encroach on the courtesy of those to whom this circular is sent out. The results of this investigation will be published and made available to all, and it is the earnest hope of the undersigned that you will generously respond with such information as you possess on the subject.

Yours respectfully,

W. C. HAWLEY,
W. C. HOAD,
EMIL KUICHLING,
R. S. LEA,
DABNEY H. MAURY,
R. WINTHROP PRATT,
F. A. BARBOUR, *Chairman.*
Committee of N. E. W. W. Association.

TABLE 2. — Part I.

Particular Experience in Freezing of Pipes.

No.	Location	Size of Pipe.	Whether Supply Main or Distribution System.	Depth to Axis.	Length of Pipe at this Depth.	Character of Soil.	Whether in Street or Field.	Depth of Ground Water at Location of Frozen Pipe.	Depth to Which Ground was Frozen.	Was the Ground Bare of Snow?	Date of Freezing.	Result of Freezing, Whether Total or Partial Stoppage.	If Partial Stoppage, State Thickness of Ring Found Inside Pipe.	Temperature of Air which Resulted in Freezing of Pipe.	Duration of Cold Period.	Did the Low Temperature Described Follow Immediately a Warm Thawing Period?
	Maine															
2	Bangor															
3	Brewer	1"-1"			20	G	S		6	Nearly	January	Total			Several weeks	Yes
4	Rumford															
	New Hampshire															
5	Dover	6" 4"	D	4' 6"	150	G	S			Yes	Winter 1906	Total		−30°	1906, all winter	Continuous cold
6	Manchester	6"	D	5' 6"				6	5' 6"	No	February	Total		0°	Four weeks	No
7	Nashua															
	Massachusetts															
8	Billerica	6"	D	6'	200	Large boulders and G	S	0	6½'	Yes	Winter, 1905	Total				Warm weather followed discovery
9	Boston							During the winter of 1903 careful measurements were made of the actual depth to which the frost penetrated. The average depth of frost in 26 different trenches was 4.4'. In all cases the ground was bare.								
11	Cambridge															
14	Hyde Park	4"	D	4' 9"	50–75'	G	S	Quite deep	5'	Yes	3 years ago	Total				
16	Lowell (locks and canals)	8"	D	Pipe exposed under bridge	75'						Jan., 1895	Total		−2 to +7°	3 days	No
17	New Bedford	4", 6", 8"	Always D	One instance, 4' cover	150' 4"	G and ashes	S	Below pipe	5'	1" or 2" of ice	Jan., 1904	Total		25 to −2°	Long period	We notice often that after a thaw has commenced service pipes will be caught by the frost
18	Reading															
19	Sharon	1½"	D	4' 6"	341'	Hp	S	0	5'	Ground covered except space 8' x 10', which happened to come in just the right spot to freeze	Feb., 1904	Total for 5' or 6'		−0°	5 weeks	No
13	Fall River	6", 8", 10"	D			G	S			Yes						
21	Stoughton	6"	D	4'	¼ mile +	C, G	S	Below except under stream	4' +	Yes, covered with ice	Feb., March, 1905	Total			2 or 3 weeks	
22	Westfield	2" and 4"	D			G	S	Below pipe	5'	Yes		Total				
	Connecticut															
24	Bridgeport	4", 6", 8", 10", 16"	D	3' 6" to 4'	25 to 150	Varied	S	Below pipe	Around pipe in each case	Both		Total		0 to 20°	Several days	
25	New London															
27	Rockville	6"				G	S	0	Have had frost 5' deep	Yes	Late in Jan.	Total		0° and below	Several days	Steady cold
	New York															
29	Canandaigua	16"	D	42"	100'; about 30' frozen	Hp	S	10'		Yes	March 1904	Total		Long spell of zero weather	February and March	No
87	Rochester															
30	Woodhaven Water Co., New York City															
31	Waterford	8"	D	4' 6"	56	G	S	0	5' 6"	Yes	Jan., 1903	Total		−28°	4 months	No
		6"	D	5'	100	Sandy loam	S	0	5' 6"	Yes	Feb., 1903	Total		−28°	4 months	No
32	Yonkers	4"	D	3'	50	Hp, R	S	0	3'	Yes	1903–04	Total		10°	6 months	
	Pennsylvania															
33	Lewiston	4"	D	3'	300	Alluvial	S			Yes	Several times previous to 3 years ago	Total				
34	Mauch Chunk	4"	D	4'	250	Red shale	S	6	2' to 2½'	Yes	Jan., 1888	Total			2 months	Yes
35	Monessen															
36	Reading	6"	D	2'	100	C	S			No		Total				
39	Westmoreland Water Co.															
40	Williamsport	4" and 6"	D	4' 6"	100–500	G	S	10' ±	5' or more	No	Jan. and Mar.	Total		Above freezing		Yes, so warm that parties did not anticipate it freezing and had shut off all circulation. Pipes were dead ends
42	York	4" (2 cases)	D	12" and 24"	75	G, C	S	25' and 10'	32"	Yes	Feb. 1904	Total			11 days	Yes
	Maryland															
43	Baltimore															
	Ohio															
44	Cleveland	4"	D	4½'–5'	700, 500, 500, 500 } 1885; 406 (1904)	Coarse sand mixed with gravel	S	Below pipe. Probably 20" below surface	Below pipe	Yes	Feb. 1885; Feb., 1904	Total		Cold wave, 1885, 0 to −15°. 1904, +1 to −8°	3 weeks ±	Yes
46	Hamilton															
56	Springfield	3"	D	3' 11"	600'	C	S	Below pipe	3½'	Yes	Feb. 1896	Total		0° and below	3 months	No
57	Warren	2"	D	3'	50'	C	S	Below pipe	3'	Yes	February	Total				
	Indiana															
58	East Chicago	4"	D	18" to 24"	500'	S	S	4'	4'	Snow in places	Feb. 1904	Total			Several weeks	No
	Illinois															
59	Belleville	4"	D	18"	100'	C	S		18"	Yes		Total		15°	Several weeks	
60	Elgin	6"	D		4 blocks	G mixed	S	Below pipe	4' 6" to 6' 2"	Ice	Jan. 1895	Total		20°	20 days	Yes
61	Mattoon															
62	Peoria	4"	Hyd. br.	3' 6" cover		S, G	S	Below pipe	4	5" snow	Feb. Mar. '99	Total		−22°	Jan. 22 to Feb 16	No
		4"	D	3' 6" cover	250	S, G	S	Below pipe	4	5" snow	Feb. Mar. '99	Total		−22°	Jan. 22 to Feb 16	No
		4"	D	3' cover	175	S, G	S	Below pipe	4	5" snow	Feb. Mar. '99	Total		−22°	Jan. 22 to Feb. 16	No
	Iowa															
71	Mason City															
72	Muscatine															
	Wisconsin															
64	Ashland	4"	Hyd. br.	6' 3"	15'	C	S		7'	Yes for 3 months	March, 1901	Total		No unusual change in temperature	The surface of street around hydrant had been bare of snow since early December. No warm period	
	Canada															
79	Brantford, Ont.									Yes	Jan. 9, '08	Total		−12°	About 12 days	Yes
80	Kingston, Ont.	3" and 4"	D	4'	500'	B	S	6'	4'–6'	No	Feb. 16	Total		−30°		Yes
81	London, Ont.	4"	D	3'	250'	S	S	5'–9'	4' 6"	No	Jan. 6, '09	Total		19°	3 to 4 days	Yes, January 4 40.5°
82	Pembroke, Ont.	4"	Hyd. br.	5' 9"	8'	C boulders	S	Below pipe	Below pipe	Yes		Total		−40° +		No
83	St. Catharines, Ont.	6"	D	4' 6"		G, S	S	10'	6'	Yes	Feb. 1888	Total		−12°	Several weeks	Yes
84	Winnipeg, Man.	6" and 8"	D	8'	6' 6"; 10' 8"	C	S	No water in trench, but 8" sewer crossed trench and etc. froze.	Ground frozen about 6' down, but frozen earth and snow being put in around pipe froze it	1' to 3' snow on ground	Feb. 2 to Apr. 21	Total			Nov. 1 to March 30	
86	Edmonton, Alberta	4"	S	5'	1,000'	C	S	Below pipe	6'	No	March 1, '09	Total			The date that this matter was first brought to our notice was March 1, but as there had been a few weeks of cold weather previous to the total freezing, the freezing did not occur altogether on this date but was caused by the continuous cold weather forcing the frost each day deeper into the ground	No

TABLE 2 PART II

		Probable Velocity of Flow through Pipe at Time of Freezing. Give Rate and Hours of Pumping if a Force Main, Number of People Supplied and Gallons per Capita Consumption if a Gravity Main or Distribution Pipe	If You have Any Experience in the Freezing of Stop Valves State Size and Whether Placed Upright or Horizontal, also Whether Placed in Masonry Vaults	If You have Any Experience in Ice Formation in Standpipe or in Vertical Riser Pipe to Standpipe State Details of Incident with Account of Temperature, Covering of Feed Pipe and Velocity of Flow in Pipe	Remarks
	MAINE				
2	Bangor		Have had trouble with large valves placed upright not in masonry vaults.	Not any trouble with ice in standpipe.	
3	Brewer				
4	Rumford			Our standpipe is on high ground and the river is not exposed. When our supply was from the river, until 4 years ago, we had more cases of services freezing and pipes in the houses, and ice 1 or 2" thick formed around riser of standpipe. Since using the ground supply there have been only a few cases of freezing in services and no ice in standpipe.	
	NEW HAMPSHIRE				
5	Dover	Dead end		No	
6	Manchester	None		No	
7	Nashua				In the past there have been freeze ups on 6" dead ends with shallow covering, say 3½ to 4'. These mains were lowered so as to obtain 5' cover; since then no trouble has occurred. "Freeze ups" occurred on several hydrant branches where the ground was cleared of snow during a long period of low temperature. Our supply, being ground water with a relatively high temperature at wells and springs, in connection with a small reservoir with a capacity of only 33 per cent greater than the daily consumption, must give in circulation a freshening and warming up that systems having a surface supply and a distribution storage reservoir do not get.
	MASSACHUSETTS				
8	Billerica	Dead end		No experience [illegible] constructed to supply takers in 1899	Have had service pipes frozen in and around cellar walls. These were put in by [illegible] the ditches not properly rammed, cellar walls not [illegible] pointed up, or service pipes laid to the required depth. Have laid our own services last 7 years. Cover everything 4½' and have yet to find a [illegible] frozen pipe.
9	Boston				The water pipes were originally laid 4' deep in Boston. Serious freezing resulted. In 1894 depth increased to 4½' to axis. Serious freezing again resulted on dead ends. In 1892 depth again increased to 5' to axis. No freezing of mains has since taken place.
11	Cambridge			No	All of our troubles from freezing have been on supply pipes and those in streets where car tracks are located and the snow removed by the railroad company.
14	Hyde Park	No flow		[illegible]	Service pipes occasionally freeze up, usually on private land and where not covered as deeply as we cover in street.
16	Lowell [illegible]	Almost none		No	Have used felt, tarred, sawdust and hair where service pipes are exposed or too shallow.
17	New Bedford	Very little if any. Freezing always in distribution system and at dead ends, with very slight velocity. Never have had a large main freeze			
18	Reading			No vertical riser in standpipe. Inside ladder was broken down by ice [illegible] and was not replaced. No trouble since.	
19	Sharon	None only 3 houses being on this pipe. Primary cause of freezing was filling of a hole with small stones after pipe was laid in street to within 6" of the pipe		In 1904-05, during a cold period, ice about 3" thick formed on side of tank, which, when sun came out thawed and fell inside until accumulated mass was about 2' in thickness, when it pulled away and broke in sections carrying away about 30' of iron ladder inside tank and pulling 3 or 4 tap bolts through the sheet, but otherwise did not damage tank much. The consumption at night being small, water in tank will drop only about 12" an hour, giving a good chance to make ice during a severe cold spell. The ice will show above top of tank 2' or more, which indicates a pretty good thickness of ice.	
13	Fall River				
21	Stoughton	Dead end		No	
22	Westfield				
	CONNECTICUT				
24	Bridgeport	Dead ends. Practically no velocity. It is the writer's opinion, based on close observation, that any appreciable velocity will prevent freezing in a water main exposed [or] buried			
25	New London				Service pipe formerly laid 2½' deep froze cold winters. Mains exposed to air, bridge crossings, etc. have frozen, but not when water was circulating. Water in tank freezes 4' or 5' deep, water in reservoir, 1' to 2' deep. Frost will run along a pipe for a long distance, and the pipe may be frozen, although the ground around the pipe is not frozen.
27	Rockville			No	
	NEW YORK				
29	Canandaigua	Dead end [illegible] 1400 gallons per day			
87	Rochester				No main regularly laid at a depth of 4½' to top of pipe has ever been found frozen, and only 3 or 4 cases in all have been found since the establishment of the water works 34 years ago. Hydrant branches have been frequently frozen where for necessary reasons the branches have been laid to less than the normal cover, and even some of the branches at our regular depth have frozen, and would freeze frequently, were the hydrants not regularly inspected and flushed in cold weather. Water mains (8") crossing the Genesee River on highway stone arch bridges have frozen and burst. These mains were laid underneath the sidewalks of the bridges with only 4" or 5" of covering, all that could be obtained. At the time they were repaired they were boxed up and surrounded with charcoal, but as an additional precaution, each winter a small circulation is maintained by opening a tap in the main at one end of the bridge and allowing the water to run freely and constantly to waste. Some few other cases have occurred of frozen mains at dead ends where there was no circulation and pipe laid at an insufficient depth.
30	Westhaven Water Co., New York City				Some years ago the grades of streets were cut down in many parts of our territory and mains not lowered in proportion, consequently the next severe winter we had a good many mains freeze and burst. Most of these were less than 2' to bottom of trench and were small (4" and 6"). We had an 8" main within 18" of the surface that did not freeze (distribution main). We used the electric current for thawing out some mains quite successfully at that time. Aside from this winter, after which we lowered mains wherever they had frozen, we have had practically no experience with mains freezing.
31	Watertown	[illegible] end		Standpipe No. 3 was built with cone-shaped roof made with steel angle iron rafters, running from top angle iron on upper sheet to a common center and fastened to a heavy casting, cross braced and all covered with sheet steel. In 1903 pack ice formed in standpipe very heavy. It would settle down at night, when pumps were shut down, and in starting pumps would block and jam together. As the pressure forced it up huge masses of ice, in some cases over a ton, would shoot up out of the mass with great force until the whole jam was forced up. It forced so hard against the roof structure and braces that it caused a rupture at the bottom row of rivets on the fourth sheet from the top and buckled the fifth sheet. I would never put a roof on a standpipe in this climate without providing a way to prevent pack ice from forming inside. Neither should a ladder or projection of any kind be placed inside. Standpipe enclosed in masonry tower.	About one half our system is in slate rock, and although laid very shallow we have no trouble from frost in this section. On May 10, 1904, we found a 4" service in a shady place in clay and loam 5' deep frozen and solid full of ice. Do not know how long it had been frozen.
32	Yonkers	[illegible]			Flow in our supply mains constant whether consumption is large or small. For this reason our supply mains in some places are covered by a few feet of ground, and as yet have never had any supply main freeze up.
	PENNSYLVANIA				
33	Lewiston	Freezing was caused by lack of circulation and was remedied by placing blow-off and opening same during cold weather			Only four cases of service freezing during the past 8 years. We thaw by electricity and act promptly.
34	Mauch Chunk	8 families, say 35 people. In digging up the services which started trouble found only 22" to 24" top of pipe in gutter. Primary cause service freezing and extending into main	No		
35	Mo[illegible]				Had 150' of 4" distribution pipe wholly exposed from 1880 to 1905 without freezing. The circulation was good. Had a 6" and 8" distribution pipe frozen. Both wholly exposed. Both dead ends owing to closing of valves. Temperature 10° for 4 days, 1903-04.
36	Reading	Dead end	No		None except on bridges or exposed points. We have places where street grade has been cut, and where our mains have not been lowered, where covering does not exceed from 1' to 2'. If street be paved with fire brick or other suitable material, our experience indicates such is worth a foot of covering.
39	Westmoreland Water Co.		No		We lay our mains in a 5' trench in streets, not for fear of their freezing, but to compel services to keep down in streets.
40	Williamsport		No		
42	York				
	MARYLAND				
41	Baltimore				Freezing in water mains is not a problem in this climate. It occurs only in extremely cold winters and then only on service pipes where the pipes had been laid by the property owners (from curb cock to house) too shallow. Freezing of mains is very rare and then only small mains in light [illegible]
	OHIO				
47	Cleveland	Not ascertainable for 1885. For 1904 dead end pipe. Connections were one 4", one 1", one 4". Probably no flow at end of pipe for [illegible] hours at night. Approximate number of persons supplied on line 130. Consuming per capita 100 gallons	February and March, 1904 ice [illegible] had formed inside the domes of two 30" and two 24" horizontal valves and one 16" vertical. These were all valves on connections between mains and had been off. Ice was sufficient to prevent opening until thawed out with steam. 30" and 24" valves in brick vaults. 16" had iron valve box. No trouble with valves that are on [illegible]		On the flats, where ground water is encountered, mains and services are not lowered, provided they are covered with water. [illegible] We have had for 10 years a 10" main crossing one of our river bridges which was exposed and never froze. The pipe has been replaced during summer of 1908 with a 16" pipe for greater capacity. Length of bridge 550'.
49	[illegible]				
56	[illegible]	Dead [illegible]			
57	[illegible]				
	[illegible]			[illegible]	I have watched the systems [illegible] I would [illegible] take the chance of freezing.
59	[illegible]	Dead [illegible]			My experience has led me to believe that mains [illegible]
60	[illegible]		In cases [illegible] dead ends.	[illegible]	[illegible]
61	[illegible]		[illegible] basement [illegible] wall of basement [illegible]		
	[illegible]	[illegible]			
	IOWA				
71	Mason City				The trouble we had in February, 1905, was on dead ends mostly where [illegible]
72	Muscatine			The temperature of our ground water is about 50°. We have not had [illegible]	[illegible]
84	[illegible]				While it is our rule to lay all pipes with a [illegible]
	[illegible]	No flow, [illegible] frozen			We have been careful to [illegible]
85	[illegible]	[illegible] 100 gallons per capita	[illegible]	[illegible]	[illegible]
81	[illegible]	Dead ends. No flow			
82	[illegible]				
86	[illegible], Ont.		No	All [illegible]	[illegible]
	[illegible]	[illegible]			During the severe winter of 1904-05 [illegible]
88	[illegible]				
89	[illegible], Alberta			We have had [illegible]	With reference to the case of water main freezing as mentioned, I may say that this was a 4" supply main running from the city level over a hill [illegible]

December 30, 1908.

(CIRCULAR.)

NEW ENGLAND WATER WORKS ASSOCIATION.

Statistics Relating to Depth of Laying Water Pipe.

Kindly fill in and return this data to FRANK A. BARBOUR, Chairman Committee on Depth of Laying Water Pipe, 1120 Tremont Building, Boston, Mass.

Date of reply.........., *Name*................, *Official position*..........

.... *Water Works*, *City or Town*.......... *State*..........
{ Municipal or Company Works. Give name if latter. }

General Data.

1. *Temperatures.*
   Mean yearly temperature, degrees F.
   Mean temperature, coldest month.
   Extreme minimum temperature and date of occurrence.
   Minimum temperature at source of supply and date of observation.
2. *Location of City.*
   Distance from ocean.
   Elevation above sea level.
3. *Source of Supply.* (Surface or ground water.)
4. *Method of Distribution.* (Gravity or pumping.)
5. *Elevated Storage with Pumping System.* (Whether reservoir or standpipe.)
   Size and depth of reservoir or standpipe.
   Reservoir or standpipe open or covered.
6. *Capacity of Reservoir or Standpipe in Relation to Daily Consumption.*
7. *Hours of Pumping Daily in Period of Minimum Temperature.*
8. *Approximate Hourly Rate of Pumping during Winter Months.*
9. *Does Pumping Entirely Cease at Night during Coldest Weather? If Not, Give Minimum Hourly Pumping Rate.*
10. *Size of Supply Main, either Gravity or Pumping.*
    If supply is by gravity, state whether delivery is practically uniform or whether it is variable.
    If variable, give the minimum rate and number of hours.
11. *Character of Soil.* (State whether rock, hardpan, clay, sand, gravel, or alluvial.)
12. *General Depth of Ground Water.*
    In route of supply main.
    In distribution system.
13. *Depth to which Frost Extends in Streets.*
    Average depth.
    Maximum depth in gravel.
    Maximum depth in clay.
    Maximum depth in sand.

14. *Depth to which Frost Extends in Fields.*
   Average depth.
   Maximum depth in gravel.
   Maximum depth in clay.
   Maximum depth in sand.
15. *Average Snow Covering.*
   In streets.
   In fields.
16. *Is Ground likely to be entirely Free from Snow during Days or Weeks of Coldest Weather?*
17. *Depths at which Pipes are Laid.*
   Supply Mains. (If depths are changed in soils of different character, specify.)
      Diameters. (Depth to axis of pipe.)
         In streets.
         In fields.
   Distribution system.
      Diameters. (Depth to axis of pipe.)
         In streets.
         In fields.
   Do you take into account the effect of different pavements in streets?
18. *Service Connections.*
   Character. (Describe method of connection with main, whether tapped on top or side.)
   Size.
   Depth.
19. *Hydrant Branches.*
   Size.
   Depth.
   Average length.
20. *Hydrants.* (State method of providing for drainage.)
21. *Number of Cases of Freezing Yearly.*
   In mains.
   In services.
22. *Are the Depths of Pipe, in your judgment, generally Sufficient, except under Extreme Conditions of Temperature?*
23. *Do these Unusual Conditions Occur with Sufficient Frequency to justify a General Lowering of the Pipe System?*

Particular Experience in Freezing with Pipes.

If you have had any experience in the freezing of pipes, state details as follows:

Size of pipe.
Whether supply main or distribution.
Depth of axis.

Length of pipe at this depth.
Character of soil.
Whether in street or field.
Depth of ground water at location of frozen pipe.
Depth to which ground was frozen.
Was the ground bare of snow?
Date of freezing.
Result of freezing, whether total or partial stoppage.
If partial stoppage, state thickness of ring of ice found inside the pipe.
Temperature of air which resulted in freezing of pipe.
Duration of cold period.
Did the low temperature described follow immediately a warm, thawing period?
Probable velocity of flow through pipe at time of freezing. (Give rate and hours of pumping if a force main; number of people supplied and gallons per capita of consumption if a gravity main or distribution pipe.)

If you have any experience in the freezing of stop valves, state size and whether placed upright or horizontal; also whether placed in masonry vaults.

If you have any experience in ice formation in standpipe or in vertical riser pipe to standpipe, state details of incident with account of temperatures, covering of feed pipe, and velocity of flow in pipes.

Remarks.

DISCUSSION.

Mr. F. A. Barbour.* I may say that whatever of value there is in this report, aside from the statistical value, is largely comprehended in the diagram (Fig. 1) indicating the relation between depths at which pipe is laid and the mean temperature of the coldest month in the average year in different parts of the country. This diagram covers a variation of mean temperature from zero to 45°. One city in Canada is shown with a mean temperature of coldest month of zero and pipes laid at a depth of 8 feet. At the other extreme appear places with a mean temperature of coldest month of 40° and the pipes laid at a depth of 3 feet. The returns from various cities and towns have been plotted and a line representing the average relation of depth to the mean temperature of coldest month has been drawn.

It is interesting to note that from the information received there are no more cases of freezing in those places where the depth of the pipe is less than in those where the depth is greater

* Boston, Mass. (Chairman of the Committee on Depth of Water Pipe.)

than that shown by the average line. It must, therefore, be concluded either that this variation in the depths at which pipes are laid in different localities with the same mean temperature of coldest month are to be explained by peculiar local conditions, or that in some places the depth shown is unnecessarily great. Personally, the speaker believes that it is safe to lay pipes where there is an assured circulation at all times, at depths less than are frequently adopted in present practice.

MR. LEONARD METCALF.* Mr. President, it seems to me that the Association is to be congratulated upon this excellent report of Mr. Barbour's committee. I think many of us recognized that any inquiry of this sort was bound to give negative results, for the most part, but it certainly gives us a good record for what current practice is, and I think it brings home to all of us the desirability of following up carefully any cases of frozen pipes that we as individuals may have. The freezing of pipes seems to depend, as would be expected, more on the velocity through the pipe than anything else, and it is on that very fact that we have the fewest data, as it is very difficult to get information of that sort. It is to be hoped that we may hereafter have some experience discussions before the Association, when members who have had recent cases of frozen pipes will tell us about their troubles.

MR. R. C. P. COGGESHALL.† I don't know what has been the experience of others, but Mr. Barbour touched on one thing in the report that we have noticed several times, and that is that when a thaw comes after a long period of cold weather, when there have been some services frozen, other service pipes in the immediate vicinity will catch or stop. I have always been puzzled about it, and have thought there was a good deal of moonshine in the idea, but still the facts seem to indicate that there is something in it, and Mr. Barbour's explanation is very interesting to me. I should like to know if others have had this same experience.

MR. GEORGE A. STACY.‡ Mr. President, we had a small main that we laid through rock during the late fall, and the back filling, perhaps, was a little rougher than it would have been if there

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* Of Metcalf & Eddy, Boston, Mass.

† Superintendent Water Works, New Bedford, Mass.

‡ Superintendent Water Works, Marlboro, Mass.

hadn't been frost in the ground. It was practically at a dead end, as there was hardly any circulation beyond at that time, although there were houses building. In the spring there was a stoppage in the pipe, and it was on a day when the water was running in the streets and you could go around in your shirt sleeves with comfort. We located the stoppage by the hydrant connections near this ledge. I noticed that the water was running down in places between the stones of the back filling which had been done in the fall, but in a very small stream. As it was then in the middle of the afternoon we made provision to allow everything to remain as it was so as not to have to work all night, for there wasn't enough to do to warrant that expense, and we could make other arrangements that would be a good deal cheaper. We expected to bring up the work gang in the morning and tackle the job, thinking that if the water could run down through the rock we wouldn't have much trouble in getting down to the pipe. The next morning, however, when we went down there with the gang, everything was all right; it had thawed out itself. The only reason I could give for it in this case was the state of the weather, the open condition of the back filling as it settled, and the action of the high temperature that day and the refrigeration, or action of that nature, causing the water in the pipe to freeze, as there was scarcely any circulation there at all. We never had any trouble at that place afterwards, and that was quite a few years ago.

Mr. Charles W. Sherman.* The fact stated by Mr. Barbour that he has had no reports of pipes larger than 10 inches in diameter which have frozen, and very few pipes larger than 6 inches in diameter, would seem to suggest the possibility, at least, that pipes of the larger sizes might to a greater extent than is now the practice be advantageously laid at a lesser depth than the smaller pipes.

Mr. John H. Flynn.† I have had a 36-inch pipe freeze and burst, and still not be frozen solid. It was laid on a trestle over a river, 600 feet or more of pipe, and 12 lengths split the whole length, and they were not frozen solid. I don't know whether anybody else ever had any such experience.

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* Principal Assistant Engineer, Metcalf & Eddy, Boston.
† Boston, Mass.

PROCEEDINGS.

NOVEMBER MEETING.

HOTEL BRUNSWICK,
BOSTON, November 10, 1909.

The November meeting of the Association was held at the Hotel Brunswick, Boston, on Wednesday, November 10, 1909.

President Robert J. Thomas presided.

The following members and guests were present:

MEMBERS.

M. N. Baker, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, T. H. Barnes, H. K. Barrows, J. F. Bigelow, A. E. Blackmer, E. C. Brooks, A. W. F. Brown, James Burnie, George Cassell, J. C. Chase, J. H. Child, C. E. Childs, H. W. Clark, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, J. H. Cook, J. W. Crawford, G. E. Crowell, G. E. Cutting, Jr., A. O. Doane, G. H. Finneran, J. H. Flynn, A. N. French, F. J. Gifford, C. W. Gilbert, T. C. Gleason, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, F. C. Hersey, Jr., J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. Kimball, G. A. King, J. J. Kirkpatrick, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Martin, John Mayo, Leonard Metcalf, William Naylor, T. W. Norcross, F. L. Northrop, E. M. Peck, T. A. Peirce, W. H. Richards, Charles Saville, A. L. Sawyer, W. H. Sears, E. M. Shedd, C. W. Sherman, H. O. Smith, G. H. Snell, G. A. Stacy, T. V. Sullivan, W. F. Sullivan, R. E. Tarbett, R. J. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, W. H. Vaughn, J. C. Whitney, G. E. Winslow. — 72.

ASSOCIATES.

Anderson Coupling Company, by C. E. Pratt; Ashton Valve Company, by C. W. Houghton; Harold L. Bond Company, by Harold L. Bond; Builders Iron Foundry, by A. B. Coulters and F. N. Connett; Chapman Valve Mfg. Co., by Edward F. Hughes; Darling Pump and Manufacturing Company, by Herman H. Davis; F. H. Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by H. D. Winton, A. S. Glover, and W. A. Hersey; International Steam Pump Co., by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller, Manufacturing Company, by George A. Caldwell; National Meter Company, by H. L. Weston, J. G. Lufkin

and C. H. Baldwin; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith, Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; United States Cast Iron Pipe and Foundry Company, by Frank E. Nevins; Waldo Brothers, by H. E. Browne; R. D. Wood & Co., by W. F. Woodburn. — 29.

GUESTS.

Messrs. Frank S. Baily, W. E. Hannan, Fred S. Gore, and Joseph Weeks, Boston, Mass.; James J. Kirby, Fall River, Mass.; James T. Davidson, Lawrence, Mass.; Walter Beals, Middleboro, Mass.; William F. Williams, New Bedford, Mass.; Percy Warren, Weston, Mass.; John C. Hoyt, Washington, D. C. — 10.

A communication was received from the Boston Society of Civil Engineers inviting members of the Association to attend a lecture in the evening by T. Howard Barnes, engineer of the United Fruit Company, on "Engineering Works, People, and Conditions in Central America."

The following names of applicants for active membership were read by the secretary: Herbert H. Barnes, Hotel Brunswick, Boston, Mass., president of the Hartford, Vt., Water Company; Percy Warren, Weston, Mass., superintendent of Weston Water Company; Guy C. Emerson, Boston, Mass., superintendent of streets, Boston; D. G. Thomas, Denver, Colo., chief engineer of the Denver Union Water Company; Walter L. Beals, Middleboro, Mass., clerk Middleboro Water Works; Lyman P. Thomas, Middleboro, Mass., civil engineer.

On motion of Mr. Collins, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so, they were declared elected.

The President read the following letter:

BILLERICA WATER WORKS.

OFFICE OF WATER COMMISSIONERS.

NORTH BILLERICA, MASS., October 29, 1909.

TO THE EDITOR
NEW ENGLAND WATER WORKS ASSOCIATION,
14 Beacon Street, Boston:

Dear Sir, — As a matter of special information to the writer, and of general interest to many readers of your magazine, I would like to suggest the collection

and publication of information as to the conditions under which extensions of water mains are made by town-owned water supplies.

In going through the files of the JOURNAL I find only meager references to this matter, and my idea would be to cover the following points, and such others as you may think pertinent:

1. Are extensions made by vote of town or controlled by water commissioners?
2. Is a guaranteed revenue required before putting in extensions, and if so, what per cent. on cost, and what items, are included in said cost?
3. If a guarantee is required and is provided for by town by-law, quote latter.
4. Quote the form of guarantee.

If the suggestion seems practicable, the sooner it is taken up, the greater value the information obtained would be, as matters in this relation come up at many of the spring annual meetings.

Yours truly,

(Signed) JOSEPH F. TALBOT,
Chairman Water Commissioners.

THE PRESIDENT. The Executive Committee has voted to recommend the appointment of a special committee of five to take up the matter referred to in Mr. Talbot's letter and report on it later.

On motion of Mr. Sullivan, of Nashua, it was voted to accept and adopt the recommendation of the Executive Committee.

The President subsequently appointed the following committee: Messrs. Charles W. Sherman, Edwin C. Brooks, A. W. F. Brown, George H. Robertson, and Norman McMillen.

THE PRESIDENT. The Executive Committee passed a vote to-day instructing the Secretary to send out postal cards to all the members, requesting them to forward suggestions as to the place for holding the next annual meeting in September, 1910. The committee believe that we ought to take action upon this matter earlier than we have sometimes in the past, and would like the advice of the members. We hope that replies will be sent in so that the result can be reported at the next meeting, December 8.

MR. WILLIAM H. THOMAS.* Mr. President, unless the committee suggests some names, I think you will get quite a wild sort of a return. I suggest that a list of places be offered to the members to select from. I might say, for instance, that I would like to go to New Haven, but perhaps there would be no accom-

* Superintendent Water Co., Hingham, Mass.

modations there for us. The committee knows where the accommodations are, and many of us do not. It seems to me, therefore, that if a certain number of places were suggested by the committee it would, perhaps, bring the matter to a head better.

The President. That was mentioned at the meeting, but it was urged that the suggestions the members might make would be simply advisory; there would be nothing final about it. We thought we would get the sentiment of the members and afterwards, of course, we would use our own judgment in the matter. [Laughter.] We want to give you all an opportunity to be heard, anyway. Is there anything else to be called to our attention before we proceed with the regular program of the afternoon?

Mr. Edwin C. Brooks.* Mr. President, a little "experience" might be of interest to some of you good people who are running a Smith tapping machine. It isn't very often that a sleeve furnished with a Smith tapping machine is defective, but such a thing does occur once in a while, as I recently found out.

In making a cut on a 20-inch main that was rather old, and the gates not too tight, after the hole was drilled through, but before the cutter began to work, the pressure of water showed a defect in the sleeve that would not permit of using it; consequently, the next thing to do was to remove the sleeve. An inch hole in the side of a 20-inch pipe is not a pleasant thing to encounter in a ditch, and in order to get around the trouble we pulled the tools back, shut down the gate, and then removed the cutter-bar, taking off the cutter-head and the drill. Into the socket where the drill fits we put a pine plug, whittled to about the size of the drill or a little larger, and, putting the machine together, we screwed the pine plug into the hole. The thing was perfectly tight, so that we could take off the sleeve and substitute another portion without the interference with the water that we should have had if we had attempted to make the repair in any other way. I thought perhaps some of you might get into a similar difficulty some time, and if you happened to hear of this it might save you a little bother.

The President then called on Mr. William S. Johnson, sanitary and hydraulic engineer, Boston, Mass., who read a paper on

* Superintendent of Water Works, Cambridge, Mass.

"Ground Waters as Sources of Public Water Supplies." The paper was discussed by Mr. Lewis D. Thorpe, Mr. A. O. Doane, Mr. George E. Winslow, Mr. John H. Flynn, Mr. Harold K. Barrows, Mr. William S. Sullivan, Mr. Robert S. Weston, Mr. Harry W. Clark, Mr. M. N. Baker, Mr. M. F. Collins, and Mr. George A. Stacy.

The President announced that, owing to the illness of Mr. Frank A. Barbour, chairman of the "committee to gather statistics relative to the depth at which water pipes are laid, and the resulting experience with frozen pipes," the presentation of this report would be deferred until the next meeting.

Mr. Harvey S. Chase's paper on "Water Works Accounting" was also postponed.

The report of the committee "to prepare a standard specification for fire hydrants" was called for.

Mr. William F. Sullivan. I know that Mr. Lacount, the chairman of this committee, is not ready to present the report to-day. There have been several meetings of the committee in which we have gone over the matter, but Mr. Lacount is doing the bulk of the work, and is compiling specifications which we hope will meet the approval of the Association. He has invited the manufacturers, as well as water-works men, to participate, and before the next meeting he expects to have the specifications in their third draft in shape so that advance copies can be sent to all the members. Mr. Lacount's intention is that there shall be a full and free discussion of this hydrant question before the Association, so that we may get all the suggestions and the amendments necessary, so that the final specifications may be put in a form which will meet the demands and the approval of the members.

We had a meeting to-day, and Mr. Lacount recommended a conference with the National Protective Fire Association, who are working along similar lines, and I know that at the next meeting Mr. Lacount will probably be here with all the information and data which he has been preparing for many months, and be ready to present it.

The President. Has Mr. Stacy anything to say on the report or about the committee?

Mr. George A. Stacy. There is nothing to say, Mr. President, except that I hope the Association will have patience with us.

We shall be on the firing line at the next meeting, I expect, and we shall be pleased to have you find all the fault you can with what we have done, and we will welcome any suggestions you may make. The committee, as a whole, has met only twice to do much work; once, a week or so ago, and again to-day; but we have made considerable progress in getting together what I hope will result in specifications which will be satisfactory, as near as it is possible to make such things satisfactory, to all concerned, including the superintendents, those who are responsible for the action of the hydrants, and the builders.

Of course, this is a pretty large problem. We do not suppose we are going to satisfy everybody, but we do hope we are going to make a satisfactory start, so that we will have some standard to work on. At present, when we are ordering hydrants, we really don't know what we are going to get. There is nothing in the way of any exact specifications; nothing but a general statement of a hydrant. When you go into the market to buy one, you don't know whether you are going to get a 4-inch gate or a 3-inch gate or a 5-inch gate; a 4-inch base or a $5\frac{1}{2}$-inch base; whether there is going to be a bronze screw or not, or whether machine work is going to be done in the foundry, or whether it is going to be done in a machine shop where it should be done.

It seems to me that the manufacturers are not making these hydrants according to their own ideas; they make just what we demand. If we demand good hydrants and put our demands in such a shape that all manufacturers have to bid on the same basis, we shall get good hydrants. If we allow the manufacturers to build hydrants in the foundry instead of the machine shop, we will get foundry hydrants; and if any of you like that kind, why, all right; but I would rather pay a little more and have the work done in the machine shop, and get less sand in the joints and stuffing boxes than some of the hydrants have to-day. I don't mean to cast any slur upon the hydrant makers; it is our own fault that we don't demand better things. When we do make such demand, they will do anything we are ready to pay for, and we ought to be willing to pay for anything that is good, because we can't get it in any other way.

On motion of Mr. M. F. Collins, adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, November 10, 1909.

Present: President Robert J. Thomas and members Richard K. Hale, George A. King, Ermon M. Peck, Charles W. Sherman, Lewis M. Bancroft, George A. Stacy, and Willard Kent.

Six applications were received and the following applicants were recommended for membership, viz.:

Lyman P. Thomas, superintendent water works, Middleboro, Mass.; Walter L. Beals, clerk Middleboro Water Works, Middleboro, Mass.; Guy C. Emerson, superintendent of streets, Boston, Mass.; Percy Warren, superintendent Water Company, Weston, Mass.; Herbert H. Barnes, president Hartford, Vt., Water Company, Boston, Mass.

Voted: That the Executive Committee recommend to the Association that a committee be appointed for the collection and publication of information as to the condition under which extensions of water mains are made by town-owned water supplies.

Voted: That the Secretary be authorized to send to the members of the Association postal cards requesting suggestions as to place of holding the next annual convention, and asking that replies be returned before December 1, next.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

Joseph E. Beals died at his home in Middleboro on September 3, 1909. Mr. Beals was born in Middleboro March 18, 1834. He was the only son of Ebner and Lucy Beals. In 1862 he entered the employ of Albert Alden, proprietor of the Bay State Works, where he remained for thirty years, when ill health forced him to retire. After this, Mr. Beals devoted himself to work of a public nature. He has been secretary and treasurer of the Board of Trustees of the Public Library, and a member of the Water Board since the construction of the works, acting also as chief clerk and superintendent. In 1906 he was elected a representative to the legislature. Mr. Beal's first wife was Mary E. Leonard, of Bridgewater. In 1876 he married Harriet C. Bardin. Mr. Beals was a vice-president of the New England Water Works Association in 1904 and was senior editor of the Journal from 1897 to 1900.

Mr. Beals was elected a member of the Association on June 16, 1886.

Adolphus A. Knudson died suddenly at Meadville, Penn., on August 13, 1909. Mr. Knudson was born in Southport, Conn., December 15, 1845, of Norwegian parents. He is survived by a widow. Mr. Knudson had been connected with the Western Union Telegraph Company and with stock-ticker companies in New York. For many years he has been devoting himself to the study of electrolysis by stray railway currents, being one of the pioneer investigators in that field. At the time of his death he was engaged in making an expert investigation of the water mains at Meadville. Mr. Knudson was a member of the American Institute of Electrical Engineers.

Mr. Knudson was elected a member of the New England Water Works Association, September 11, 1902.

George H. Bishop died at Watch Hill on August 19. Mr. Bishop was born in Middletown, Conn., June 7, 1831. He was the son of Giles Bishop. Mr. Bishop entered the engineering profession at an early age, becoming associated with George Norman, a well-known hydraulic engineer. Since that time Mr. Bishop has designed many water systems and frequently acted as expert in the construction of water works, and has been called many times as an expert witness to give testimony concerning water rights and construction. About 1870 Mr. Bishop married Miss Purple, of Illinois. While never holding public office, Mr. Bishop took a prominent part in the affairs of the Knights of Pythias as well as other fraternal orders.

Mr. Bishop was elected a member of the New England Water Works Association on June 16, 1886.

BOOK REVIEWS.

Irrigation Engineering. By Herbert M. Wilson, C. E. Sixth edition, revised and enlarged. 8vo. xxix+625 pages, 38 full page plates, and 195 figures. New York: John Wiley & Sons. 1909. Cloth, $4.00.

The first edition of this book was published in 1893. The present edition, the sixth, has been entirely rewritten, as the author states in the preface, to bring to date the great progress made in construction work and to show the important changes in design brought about by the general adoption of reinforced concrete for the structures needed in irrigation projects.

The work is, in the main, a presentation of the current Western practice in irrigation, although it contains descriptions of many foreign works. It is, therefore, of value to the practicing engineer as giving numerous illustrations of existing works. Its principal value to Eastern engineers and water-works men is its description of the methods used in constructing the earth dams, with the piping and gate chambers, and typical specifications and the tables of the unit costs prevailing on the government work. The discussion of pumping machinery with the relative costs of the different types of plants is also interesting, though there are not enough figures as to the cost of coal and other materials and the rate of wages to make these figures comparable with those derived from Eastern practice.

The government has such elaborate methods of cost keeping in the Reclamation Service that it seems a pity that more unit costs could not be given.

The book is also of considerable value as a text-book for students' use, and particularly valuable in connection with a course in hydraulics. In such a case the chapters on the flow of water in pipes and channels, and the theory of the design of dams, could be omitted, leaving the interesting reading matter on the practical application of hydraulic problems in innumerable cases.

The book is divided into three parts: Hydrography; Canals and Canal Works; and Storage Reservoirs.

Under the first part, the author discusses:

Rainfall, run-off, stream flow, evaporation, absorption, seepage, the measurement of water flow in open channels, the quantity of water required, and the use of sewage for irrigation purposes.

In this discussion, which comprises about one fifth of the book, the author presents tables of statistics, diagrams and illustrations, and numerous lists of references for the subjects treated.

Under "Canals and Canal Works," the author presents definitions of the different types of canals; methods of aligning the slopes and cross-sections employed; headworks, diversion weirs, sluiceways, regulators, falls, distributaries; and discusses the flow of water in pipes and the methods of applying the water to the fields.

In the discussion, which comprises about one half of the book, the author goes into considerable detail, giving numerous illustrations of actual structures as well as many references.

Under "Storage Reservoirs," the author discusses their location and capacity, the construction of dams; wasteways and sluices; and pumping tools and maintenance, concluding with a short description of the United States Reclamation Service.

This part takes up about one quarter of the book and is probably the most interesting to Eastern engineers as it presents a study of reservoirs and dams, with a description of some of the big dams in the country and the cost of the storage provided. The discussion of the various methods of pumping, with the efficiency and approximate cost of each method is also exceedingly interesting.

Sanitation, Water Supply and Sewage Disposal of Country Houses. By William Paul Gerhard, C.E. 12mo. xx+346 pages, 113 full page plates and figures. New York: The D. Van Nostrand Company. 1909. Cloth, $2.00.

The author states in the preface that it has been his aim throughout the work to inform the reader "What to do" rather than "How to do it," and that he has omitted many details regarding the execution of sanitary methods, avoiding in this way the encouragement of "amateur sanitary engineering."

There is little doubt that this lack of detail results in great loss in the value of the book, particularly to the engineer and architect. With the exception of this lack of detail, the book gives a very good summary of the various subjects treated and suggests many ideas for the design of small plants. The book is well arranged and the illustrations are, for the most part, well chosen. There is, however, no index.

This book, as suggested by the title, is divided into three parts, Sanitation, Water Supply, and Sewage Disposal of county houses, institutions, and hotels located out of reach of the water and sewerage systems of the community.

In the first part of the book, Sanitation, the author discusses the desirability of sanitary surroundings, and shows the necessity of good location, ventilation, surface drainage, and the proper methods of lighting and heating. This part concerns the householder and builder much more than it does the architect or engineer.

In the second part, Water Supply, the author describes the different sources of supply and methods of pumping, distribution, and storage, followed by a description of actual plants. It seems strange that water filters are not given more consideration in this connection. It is frequently possible with very simple filters or aërating devices to purify water that could not otherwise be used with comfort. It seems to be the opinion of the best hydraulic engineers that purity of surface waters, however careful the inspection of the watershed may be, cannot be depended upon, and that the time is not far distant when state laws will compel the filtration of all public surface water supplies. It would seem, therefore, particularly in the case of institutions or sanatoria, that a consideration of this problem would be of the utmost importance.

In the third part, Sewage Disposal, the author discusses cespools, subsurface irrigation, septic tanks, contact beds, and filters. There is a good description of the different processes from an elementary point of view, followed by some plans of the various types of purification plants as actually put in.

As mentioned before, the greatest fault in the book from the point of view of engineers is the omission of the definite information so necessary for the design of such plants, as well as the relative economy of the various types. The cost of these small installations for country estates is generally in excess of those for towns in proportion to the size, and is rather difficult to estimate, so that if the author had given the cost of the various works he described he would have added greatly to the value of the book. Nevertheless, the book presents many valuable ideas in the design of such plants and should be extremely useful to architects and engineers who install them.

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GEORGE A. KING,

President New England Water Works Association,

1910.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXIV. March, 1910. No. 1.

REPORT OF COMMITTEE APPOINTED TO COLLECT DATA RELATING TO AWARDS FOR WATER AND WATER-POWER DIVERSION.

[*Presented December 8, 1909.*]

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APPENDIXES.

At the convention of this Association held in Springfield, September 12, 1907, a resolution was passed "that a committee of five be appointed by the president to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organizations of mill owners, relating to the formulation of standard rules of computing or assessing damages for the diversion of water."

ORGANIZATION OF COMMITTEE.

Pursuant to this resolution, the president appointed the following committee:

Charles T. Main, Boston, Mass.; Leonard Metcalf, Boston, Mass.; Richard A. Hale, Lawrence, Mass.; Charles E. Chandler, Norwich, Conn.; William Wheeler, Boston, Mass.

The committee met and organized, with Charles T. Main as chairman and Leonard Metcalf as secretary.

After a careful consideration of the duties of the committee in their broader aspect, the committee decided to include in its search for statistical data relating to the diversion of water or water

power, not only awards which had been made therefor by different tribunals, but also such records of sales of the right to divert power as it might be able to learn of.

METHOD OF OBTAINING DATA.

A printed circular, shown in Appendix C, was sent out to all members of the Association, and to many water-works superintendents and engineers in different parts of the country. This circular was followed by several hundred personal letters addressed by the secretary to water-works men and engineers in different parts of the country and in Canada, who it was hoped might contribute data. Subsequently, several hundred letters were sent out as second and third requests for information, and brief verbal reports of progress were made by the committee at the annual conventions held in Atlantic City and New York City, in 1908 and 1909 respectively.

DIFFICULTY OF OBTAINING INFORMATION.

The committee recognized the difficulty of its task, for data of this sort are soon buried in the files of the interested parties, or their lawyers or experts, and the assembling of the information asked for made a serious demand upon the time of the men addressed. Moreover, in many cases it was recognized that publicity would neither be desirable nor permitted. In all such instances the committee has urged that the information be given in outline, so that the basic facts might be known, without giving the names or the details in such form that the location could be recognized.

It is also perhaps worthy of note that litigation over such cases has been limited almost wholly to the Atlantic or Eastern states, and that little if any information could, therefore, be obtained from other parts of the country.

VALUE OF DATA, AND ACKNOWLEDGMENTS.

It is not for your committee to comment upon the value of the statistics obtained, but it does owe a word of appreciation and

recognition to the public-spirited men who have been willing to devote sufficient of their time to furnish the data which have actually been assembled. Your committee recognizes that data of this sort cannot be directly applied elsewhere, and that each new case must of necessity be judged upon its own merits. Nevertheless, it is hoped that the statistics accumulated are given in sufficient detail to serve as an approximate guide or aid in forming the judgment of those who have questions of this sort to pass upon, incident to the acquiring of additional water supplies or water rights of one kind or another.

SCOPE OF INQUIRY.

While a considerable amount of data, which it is still hoped may be contributed hereto as discussion, has not yet been received, your committee has thought it wiser to present its final report at the present time rather than to postpone its presentation until a later date; but any material which may be presented in the discussion of this report will be incorporated in its final publication in the JOURNAL of the Association.

The scope of the inquiry is indicated by the form of circular sent out, which is shown in Appendix C.

In order to make this report as concise as possible, in tabulating the replies received the questions have been omitted, except in so far as was necessary to make the replies intelligible. The wording of the replies received has been preserved as far as possible, and all of the essential data submitted have been included.

In the fundamental data which follow but one series of facts stated is the work of the committee, — the computation of the unit basis of award or agreed selling price; that is, the amount thereof "per square mile per foot of fall," or "per million gallons daily per foot of fall."

UNIT BASIS OF COMPARISON ADOPTED.

Why, it may be asked here, did your committee select the unit basis adopted for comparison of the information contained in these circulars?

Direct comparison was impossible for obvious reasons. A comparison of the amount of the awards or the prices agreed upon

could not be compared upon a horse-power basis without involving questions as to the character of the use, the hours of use (whether for 24-hour power, 10-hour power, or any other period), and without the exercise of judgment by the committee or of the experts employed upon the different sides of the case.

For this reason it seemed wiser to your committee to adopt as a standard unit of comparison in these cases the amount "($) per square mile per foot of fall," or "($) per million gallons daily per foot of fall." These standards are relatively fixed and easy of determination, for there is usually substantial agreement by the experts as to the extent of the watershed involved and the actual available fall. It is true that in discussing data based upon this standard the variation in yield from watersheds in different parts of the country must be clearly borne in mind. On the other hand, this variation within the limits of the data submitted is slight as compared with the difference in judgment which would have been found had the horse-power basis been adopted. Attention is also called to the fact that the figures discussed relate primarily to the payments for the water-power taken, without allowance for interest upon the award from the date of diversion to the date of award, and without allowance for such items as large adjacent areas of land, mills, tenements, or other buildings, and plant contained therein.

In figuring the amount of award, or price paid per square mile per foot of fall, the watershed actually diverted is used and not the total amount of watershed above the privilege (unless the entire amount above the privilege was diverted), and the available fall in feet (rather than the fall actually developed or utilized). Similarly, in figuring the unit "($) per million gallons daily per foot of fall," the amount of water the right to divert which was taken was assumed rather than the actual amount of the diversion at the time of the taking. And the result is given usually to three significant figures only, the limit of accuracy.

FUNDAMENTAL STATISTICS SUBMITTED.

The fundamental statistics received are submitted in Appendix B of this report.

SUMMARIZED RESULTS.

For the purpose of more readily making comparison in any desired analysis of the fundamental data, the results submitted in Appendix B have been summarized in the brief form submitted in Appendix A. This form (Appendix A) includes the statements of the total watershed above the damaged property, the amount of watershed from which water was actually diverted, the available fall, the unit prices paid, either per square mile per foot of fall or per million gallons daily per foot of fall, and a few significant remarks, — all grouped into four broad classes as follows:

Developed Privileges:

(*a*) Value on Award.

(*b*) Value on Agreement.

Undeveloped or Unused Privileges:

(*c*) Value on Award.

(*d*) Value on Agreement.

Cases in which the prices paid (either on award or agreement) cover not only the power privilege itself, but the taking of large areas of land, mill properties and plants, tenements, etc., have been enclosed in the columns of unit paid by parentheses, and have been omitted from the averages made of those columns.

The general range covered by the data accumulated is shown in the following table:

TABLE I.

	Number of Cases.	Value per Square Mile of Watershed per Foot of Fall.		
		Max.	Min.	Average
Developed privileges:				
a. By award	125	$366.10	$2.45	$76.85
b. By agreement	60	181.20	2.80	52.85
Combined (*a* and *b*)	185	366.10	2.45	69.07
Undeveloped, unused, or abandoned privileges:				
c. By award	10	15.72	0.20	7.13
d. By agreement	11	25.60	1.04	8.15
Combined (*c* and *d*)	21	25.60	0.20	7.66

The number of awards per million gallons of water diverted are so few that the reader is referred directly to Appendix A for them.

INTERPRETATION OF RESULTS.

It hardly seems necessary to allude to the fact, which must be patent to any student of this subject, that none of the results submitted can be applied directly to new cases, for the reason that no two cases are identical or even thoroughly similar.

Your committee, therefore, desires to place itself on record in urging caution in the application of the information submitted, and calls attention to a few of the considerations which must be clearly borne in mind in making comparison of conditions.

Among these conditions may be mentioned the method by which the price paid for the water or power diverted was determined, whether by agreement or by legal procedure; the knowledge and proficiency of the interested parties, or those called to their assistance; the market value of the privilege affected; the cost of development; the character of the privilege, if developed; the degree of development; the character of the use of the development; the character of the particular industry and of the industries of the community in which the privilege is located; the labor conditions; the location of the privilege in reference to railroads, water, or other transportation facilities; the yield of the streams in amount, distribution, and constancy, and the storage facilities upon them.

And, finally, in comparing the prices paid, by award or agreement, let the fact not be lost sight of that litigation is expensive, and that while awards may seem high in some cases, the actual financial return to the injured parties after deduction of the cost of litigation may be less even than could have been obtained by agreement without legal procedure. Even agreement implies compromise, and considerable sums of money are often paid by agreement to avoid the expense of litigation.

APPROXIMATE POWER DERIVABLE FROM NEW ENGLAND WATERSHEDS.

Your committee recognizes the danger of laying down approximate rules for determining the amount of power to be derived from watersheds with privileges of known fall in New England.

The subject is one requiring the judgment of one well versed in such matters, for different conditions, such as the character of the watershed, its location and elevation, the amount and control of the storage upon it, etc., will materially affect not only the amount, but, more important, perhaps, the distribution and constancy of the power to be derived from these watersheds.

For purposes of approximation, and for the benefit of those who may wish to form some general idea of the relation between the yield or flow of streams in this vicinity* and the available 24-hour power to be derived from them, the following approximate general rule may be of service:

A yearly average of approximately one tenth of one horse-power per square mile of tributary watershed per foot of fall (which corresponds to a maximum 24-hour flow or development of water of about 1.4 cubic feet per second per square mile of watershed and a maximum available 24-hour net power of 0.12 horse-power per foot of fall per square mile of watershed) *may generally be obtained economically*, and a correspondingly greater rate of output if the power be used for less than twenty-four hours per day, and sufficient pondage be available to make such concentrated use of the water possible.

Example: Thus a watershed of 45 square miles area tributary to a dam site having an available fall of 25 feet may be relied upon to develop an approximate average 24-hour power of $0.1 \times 45 \times 25 =$ 112.5 horse-power.

The yield or flow of water from the Sudbury, Nashua, and Croton River watersheds has been carefully observed for a long period of years and has shown the following average results in cubic feet of water flowing per second from each square mile of watershed, arranging the average monthly records of each year in the order of the dryness of those months instead of in the calender order of the months, and averaging these results, obtaining thus the average for a long period of years of the driest month of each year, of the second driest month of each year, the third driest, etc., to the wettest month of each year.

The Sudbury yields are stated for three different periods:

First. The twenty-three-year period from 1875 to 1897, for

* Central, southern, and eastern New England.

TABLE II.

Yield in Cubic Feet per Second per Square Mile of Watershed.

Month.	Sudbury River. (75.2 sq. mi.) (1.9% to 6.5% water surface.)			Nashua River. (118.19 sq. mi.) (2.2 to 7% water surface.)	Croton River. (360.4 sq. mi.) (4.47% water surface.)	
	23-year period, 1875-1897.	12-year period, 1897-1908.	34-year period, 1875-1908.	12-year period, 1897-1908.	32-year* period, 1868-1899.	41-year period, 1868-1908.
Driest	0.192	0.098	0.160	0.385	0.26	0.25
Second driest	0.271	0.232	0.256	0.557	0.41	0.44
Third ,,	0.434	0.431	0.420	0.722	0.55	0.59
Fourth ,,	0.582	0.614	0.551	0.903	0.74	0.76
Fifth ,,	0.771	0.730	0.741	1.022	0.93	0.97
Sixth ,,	1.049	0.871	0.976	1.182	1.20	1.24
Seventh ,,	1.303	1.048	1.210	1.401	1.41	1.47
Eighth ,,	1.598	1.719	1.644	1.861	1.74	1.82
Ninth ,,	2.225	2.314	2.273	2.431	2.18	2.24
Tenth ,,	2.801	2.761	2.800	2.811	2.73	2.78
Eleventh ,,	3.565	3.610	3.613	3.705	3.41	3.50
Wettest	4.922	4.891	4.939	4.969	4.48	4.64
Average	1.643	1.610	1.617	1.829	1.66	1.73

* See John R. Freeman's report upon New York Water Supply, p. 240.

the reason that the records of this period are believed to be more precise than the later records, as the water surfaces of the reservoirs upon this watershed were largely increased at this time, and as since March, 1898, an increasing quantity of water has been diverted from the Nashua River through the Sudbury basin, involving the measuring in and measuring out of this flow in addition to observations upon the gain and loss in storage in the reservoirs upon the Sudbury watershed.

Second. The twelve-year period from 1897 to 1908, the period during which observations have also been made upon the Nashua River.

Third. The entire thirty-four-year period from 1875 to 1908.

Attention is called to the fact that the Sudbury River yield records do not give the actual run-off of the river (which would

include the effect of storage in the wet season and draft from storage in the dry season from the tributary reservoirs and streams, as well as the loss by evaporation of water from them), but the natural flow of the watershed *without* storage, so nearly as this flow can be measured and adjusted for the change in volume of stored water, but without taking into account the actual loss of water by evaporation from the water surfaces of the existing reservoirs and streams upon this watershed. It may be said that this method of figuring the yield is common in water works or supply cases, as is the case also in the Nashua and Croton records, but upon streams utilized chiefly for power production purposes the effect of storage as well as the loss by evaporation is included in the yield or run-off measurements and records.

If we assume, further, according to the probable concensus of opinion of engineers,—

First, a wheel development at the water-power privilege being investigated, corresponding to the yield of the tributary watershed in the seventh month, arranged in order of dryness;

Second, collection of water or yield upon the tributary watershed as shown in the tabulations above, which do not cover the effect of large storage basins, to equalize the flow of the wet and the dry season;

Third, 75 per cent. efficiency in the use of water in the development of power,

the resulting net 24-hour power to be developed per square mile of tributary watershed per foot of fall will be as follows:

TABLE III.

Resulting Available Net Twenty-Four-Hour Power per Square Mile per Foot Fall from Above Assumptions, upon Basis of the Yields of the Following Rivers.

Month.	Sudbury.			Nashua.	Croton.	
	23 years, 1875-1897. Horse-Power.	12 years, 1897-1908. Horse-Power.	34 years, 1875-1908. Horse-Power.	12 years, 1897-1908. Horse-Power.	32 years, 1868-1899. Horse-Power.	41 years, 1868-1908. Horse-Power.
Driest............	0.0164	0.0083	0.0136	0.0328	0.0221	0.0213
Second driest.....	0.0231	0.0197	0.0218	0.0474	0.0349	0.0374
Third ,, ...	0.0369	0.0367	0.0357	0.0614	0.0468	0.0502
Fourth ,, ...	0.0495	0.0523	0.0469	0.0768	0.0640	0.0647
Fifth ,, ...	0.0656	0.0621	0.0630	0.0870	0.0792	0.0825
Sixth ,, ...	0.0892	0.0741	0.0830	0.1006	0.1021	0.1055
Seventh ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Eighth ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Ninth ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Tenth ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Eleventh ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Wettest ,, ...	0.1108	0.0892	0.1030	0.1193	0.1200	0.1251
Average	0.0788	0.0657	0.0735	0.0935	0.0891	0.0927
,, minimum	0.0164	0.0083	0.0136	0.0328	0.0221	0.0213

Example: The method of computation is shown by the calculations of the figure for the driest month on the Croton basis, as follows:

1 (sq. mi.) × 0.26 (c.f.s. per square mile) × 62.4 (lb.) × 1 (foot fall) × 0.75 (efficiency) ÷ 550 (ft. lb. per second) = 0.0221 h.p.

The actual wheel development or installation, which usually materially exceeds the *average* power obtainable, varies with the available water and the portion of the day into which its flow is concentrated, or during which it is used, and some other considerations or factors. In 24-hour power developments in this region the wheel development is perhaps generally designed to utilize from 1 to 1.4 cubic feet of water per second per square mile of tributary watershed, and even more in special cases; in 10-hour power developments an examination of a large number of actual mill installations upon New England streams has shown a develop-

ment to utilize approximately 1.4 cubic feet of water per second per square mile of tributary watershed, corresponding to the yield of the sixth or seventh month, arranged in the order of their dryness, of an average year; or more in special cases, depending upon the amount of available pondage adjacent to the water power plant or privilege, the character of the industry, etc.

The relation between the amount of water flowing and the horse-power obtainable from it is indicated by the following table:

1 cubic foot of water per second per square mile per foot of fall at 75% efficiency =

$$1 \text{ c.f.p.s} \times 62.43 \text{ lb.} \times \frac{1 \text{ ft. fall}}{550} \times \frac{75}{100} \text{ efficiency} = 0.08513 \text{ h. p.}$$

1.25 c.f.p.s.	,,	,,	,,	= 0.1064	,,
1.4 c.f.p.s.	,,	,,	,,	= 0.1192	,,
1.5 c.f.p.s.	,,	,,	,,	= 0.1277	,,

From Table III it appears that, for purposes of general approximation, we may assume that in New England watersheds *without* a material amount of storage and with a development up to the yield of the seventh month of an average year, arranged in the order of the dryness of those months, there can be obtained an *average* of approximately 0.09 horse-power (24-hour power) per square mile of tributary watershed per foot of fall, but the minimum power under such conditions may fall to one third or less of this amount. *With* storage the above-stated available power (0.09 horse-power) would be appreciably increased, the amount of this increase depending upon the volume and control of this storage.

In the light of all of these facts, it is perhaps safe to say, as previously stated, *that for purposes of rough approximation for* New England watersheds with some storage, there can be developed one tenth of one horse-power (24-hour power) per square mile of watershed per foot of fall*, but it must be clearly borne in mind, as stated, that local conditions, character of watershed, location and elevation, storage facilities and control, cost, and character of development and industry to be served will modify this figure materially.

UNITS.

Nomenclature.

g.p.d. = gallons per day of 24 hours.
g.p.m. = gallons per minute.
c.f.p.s. = cubic feet per second.

* Central, southern, and eastern New England.

Flow.

1 c.f.p.s. = 646 317 g.p.d. = 0.991736 inch-acre-hour.
1 000 000 g.p.d. = 1.54723 c.f.p.s. = 1.53444 inch-acre hours.
1 inch-acre-hour = 1.00833 c.f.p.s. = 651 703 g.p.d.
1 U. S. g.p.m. = 1440 g.p.d. = 0.002228 c.f.p.s.

Time.

10	hours	=	600	minutes	=	36 000	seconds.
24	,,	=	1 440	,,	=	86 400	,,
28	days	=	40 320	,,	=	2 419 200	,,
29	,,	=	41 760	,,	=	2 505 600	,,
30	,,	=	43 200	,,	=	2 592 000	,,
$30\frac{5}{12}$	,,	=	43 500	,,	=	2 628 000	,,
31	,,	=	44 640	,,	=	2 678 400	,,
365	,,	=	525 600	,,	=	31 536 000	,,
365.25	,,	=	525 960	,,	=	31 557 600	,,
366	,,	=	527 040	,,	=	31 622 400	,,

Volumes.

1 cu. ft. = 7.481 U. S. gal.
1 U. S. gal. = 231 cu. in. = 0.1337 cu. ft.

Weight of Water.

1 cu. ft. = 62.43 lb.
1 U. S. gal. = 8.345 ,,

Power.

1 h. p. = 33 000 ft. lb. per minute = 550 ft. lb. per second.
1 h. p. = 8.805 c.f.p.s. per foot fall = 5.694 m.g.d. if efficiency = 100%
1 ,, = 11.012 ,, ,, ,, ,, = 7.118 ,, ,, ,, = 80%
1 ,, = 11.746 ,, ,, ,, ,, = 7.594 ,, ,, ,, = 75%
1 c.f.p.s. per foot fall = 0.11350 gross h. p. at 100% efficiency.
= 0.09081 net ,, ,, 80% ,,
= 0.08513 ,, ,, ,, 75% ,,
1 net h. p. = 11 c.f.p.s. per foot fall at 80.09% efficiency.
1 ,, ,, = 12 ,, ,, ,, ,, ,, 73.42% ,,
1 U. S. g.p.m. per foot fall = 0.0002539 gross h. p. at 100% efficiency.
= 0.0002023 net ,, ,, 80% ,,
= 0.0001897 ,, ,, ,, 75% ,,
1 000 000 U. S. g.p.d. per foot fall = 0.1756 gross h. p. at 100% efficiency.
= 0.1405 net ,, ,, 80% ,,
= 0.1317 ,, ,, ,, 75% ,,

Run-Off.

1 in. per square mile per hour		= 645.33	c.f.p.s.	= 417 079 832	g.p.d.
1 ,, ,, ,, ,, ,,	24 hours	= 26.889	,,	= 17 378 743	,,
1 ,, ,, ,, ,, ,,	28 days	= 0.96032	,,	= 620 669	,,
1 ,, ,, ,, ,, ,,	29 ,,	= 0.92720	,,	= 599 267	,,
1 ,, ,, ,, ,, ,,	30 ,,	= 0.89630	,,	= 579 291	,,
1 ,, ,, ,, ,, ,,	$30\frac{5}{12}$,,	= 0.88401	,,	= 571 356	,,
1 ,, ,, ,, ,, ,,	31 ,,	= 0.86738	,,	= 560 505	,,
1 ,, ,, ,, ,, ,,	365 ,,	= 0.073668	,,	= 47 613	,,
1 ,, ,, ,, ,, ,,	$365\frac{1}{4}$,,	= 0.073618	,,	= 47 580	,,
1 ,, ,, ,, ,, ,,	366 ,,	= 0.073467	,,	= 47 483	,,

FORMULATION OF STANDARD RULES FOR ASSESSING DAMAGES IMPOSSIBLE.

Your committee has considered carefully, as instructed by the original vote passed by this Association, "the practicability of joint action with the National Cotton Manufacturers' Association, or other organizations of mill owners, relating to the formulation of standard rules of computing or assessing damages for the diversion of water," and has conferred with officials of various associations, and regrets that it must now report the impracticability of such action. The questions involved are so much a matter of law, the outgrowth of centuries of experience, and the nature of the problems to be passed upon is so diverse, and the interests involved are so many and even so antagonistic as to make it absolutely hopeless to attempt to formulate, or even to outline, any standard rules as suggested.

BIBLIOGRAPHY.

To round out this report, it has seemed advantageous to submit a bibliography of articles which have appeared in engineering literature relating to prices paid for water or water-power diversion. With this end in view, your committee have had a search made of the libraries of the American Society of Civil Engineers and the American Society of Mechanical Engineers, which are located in New York City, and some references have been added from the personal files of the members of the committee.

The demands upon the time of the members of your committee in the collection, collation, summarization, and discussion of the

data obtained have already been so heavy as to make it practically impossible for its members to personally read and abstract the references contained in this bibliography. The references are submitted in Appendix D, however, for the use of those whose need may make it advantageous to make more extended personal inquiries into the available literature upon this complex question.

LEGAL QUESTIONS INVOLVED IN THE DIVERSION OF WATER.

The committee felt that it would be advantageous to have presented to you as a sort of introduction to this subject a brief paper on the legal aspects of the diversion of water, the general methods of procedure, riparian ownership, etc., by some competent legal authority. It invited Charles F. Choate, Jr., Esq., a lawyer of highest rank in this city and of large experience, and well versed in cases of this kind, to prepare such a paper, and Mr. Choate kindly consented to do this in spite of the pressing demands of his practice. Your committee considers this Association most fortunate in securing Mr. Choate's coöperation in this direction.

In conclusion, your committee desires to express its appreciation of the friendly interest and coöperation of those who have contributed data for this report.

Respectfully submitted,

CHARLES T. MAIN, *Chairman.*
CHARLES E. CHANDLER.
RICHARD A. HALE.
WILLIAM WHEELER.
LEONARD METCALF, *Secretary.*

SUMMARY OF DEVELOPED PRIVILEGES. **By Award.**

Location.	Watershed. Square Miles. Total.	Watershed. Square Miles. Diverted.	Available Fall. Feet.	Award (Excluding Interest), etc. Per Square Mile of Watershed per Foot of Fall.	Award (Excluding Interest), etc. Per Million Gallons Daily per Foot of Fall.	Remarks.
CONNECTICUT.						
Cheshire, Ten Mile Brook	5.6	1.6	22.	($198.86)	....	Unusual st'age facilities.
" " " "	5.7	1.6	20.	46.87	....	
Naugatuck, Straitsville Brook	20.	1.8	35.	2.45	....	
New London, Briggs' Brook	2.	1.6	51.	(95.60)	....	Including rights of way.
" " " "	2.4	1.6	....	.....	....	Special case.
Plainville, Pequabuck River	46.4	7.2	15.1	65.		
Waterbury, Naugatuck River	20.	18.	7.	15.90	....	
" " "	23.	18.	13.	29.90	....	
" " "	23.2	18.	7.	9.52	....	
Wilton	7.	...	7. (?)	.....	....	Special case.
Windsor, Mill Brook	1.	...	20.	.....	} $449.00	200 000 g.p.d.
" " "	1.	...	9.8	.....		
DISTRICT OF COLUMBIA	...	...	....	.....	....	Special case.
MAINE.						
Waterville, Messalonskee River	204.	204.	13.	6.32	....	Including small allowance for buildings.
MASSACHUSETTS.						
Charles River, 5 mills	...	...	26.7	.....	185.40	2 m.g.d.
Ayer, Nashua River	302.	118.3	8.	21.20	....	
Braintree	...	...	....	.....	....	Special case.
Canton, Beaver Brook	2.7	2.6	20.5	18.80	....	
Easthampton, Manhan River	60.5	13.	16.	105.70	....	
Gardner	...	...	....	.....	....	$106 000 per m.g.d., about 850 000 g.p.d.
Gloucester	...	...	....	.....	....	$197 000 per m.g.d., about 890 000 g.p.d.
Haverhill, East Meadow River	7.8	7.8	9.	43.00	....	
" " " "	7.5	7.5	8.	50.00	....	
Holyoke, Manhan River	27.5	13.	13.5	49.30	....	
Hopkinton, Whitehall Pond	...	...	....	.....	....	Special case.

Hudson, Assabet River	64.3	3.4	9.	113.00	....	
Kingston, Jones River	19.8	4.4	8.	(483.00)	....	Special case.
Maynard, Assabet River	113.1	3.4	22.2	111.00	....	
” ” ”	113.1	3.4	12.0	103.50	....	
” ” ”	115.6	3.4	10.8	111.00	....	
Middleboro, Nemasket River	59.	48.1	10.	12.70	....	
Northampton, Mill River	13.	7.2	30.	27.60	....	
” ” ”	47.	7.2	14.5	145.20	....	
” West Brook	13.1	7.2	18.5	20.10	....	
” ” ”	13.2	7.2	22.5	30.90	....	
Pepperell, Nashua River	434.1	118.2	19.	49.70	....	
Southampton, Manhan River	34.7	13.	9.	13.53	....	
South Deerfield, Mill Pond	39.2	3.7	14.5	43.50	....	
Springfield, Jabish Brook	...	10.6	123.5	34.30	....	5 mills.
Stow, Assabet River	77.0	3.4	11.5	87.70	....	
Waltham and Watertown, Stony Brook	251.4	23.	12.1, 4., 4.80, 5.80	24.40	....	4 privileges.
Waltham, Stony Brook	4.1	4.1	8.	51.35		
” ” ”	23.	23.	16.	(69.29)	....	Including value for other uses of water.
Westfield, Little River	81.	6.4	8.	54.10		
” ” ”	76.	6.4	10.	95.60		
” ” ”	80.	6.4	18.			
Westvale, Assabet River	116.8	3.4	8.8	124.00	....	
Worcester, Kettle Brook cases	4 8 to 472.5	3.856	Various.	137.22	....	45 privileges. 69 mills on Kettle Brook and Blackstone River. Range of awards from \$366.10 to \$81.80 per sq. mi. per ft. fall.
New Hampshire.						
Manchester, Lake Massabesic	66.	45.	46.	24.20	....	
Nashua	29.	1.1	25.	89.70	....	Including interest and collateral items.
New York.						
Bedford	28.1	...	32.5	70.00		
Brunswick, Quackenkill River	81.	17.5	29.	47.25	....	Partially developed. Another suit pending.
Fort Plain, North Creek	81.	4.65	19.	57.20	....	4 owners.
Franklin	...	...	....	.....	....	Special case.
Lewisboro, Cross River	3.72	3.72	7.8	311.		
” ” ”	16.5	16.5	11.5	94.70		

SUMMARY OF DEVELOPED PRIVILEGES.

(*Continued.*)

By Award.

Location.	Watershed. Square Miles. Total.	Watershed. Square Miles. Diverted.	Available Fall. Feet.	Award (Excluding Interest), etc. Per Square Mile of Watershed per Foot of Fall.	Award (Excluding Interest), etc. Per Million Gallons Daily per Foot of Fall.	Remarks.
NEW YORK.						
Little Falls	...	...	....	.....	....	Special case. Data incomplete.
Pittstown, Tomhannock Creek	1.8	1.8	20.	($91.40)	....	Including some land and houses.
" " "	10.	10.	24.	(70.80)	....	Including land and houses.
Rochester, Hemlock and Canadice Lakes	202.3	62.4	270.	11.30	$43.50 11.90	22 owners, 24 privileges. First diversion, 9 m.g.d. Second " remaining yield, approx. 20 m.g.d. Second diversion payts. were on agreement.
Schagticoke, Tomhannock Creek	69.	67.	18.	13.70*		
NORTH CAROLINA.						
Durham	120 (?)	...	11.	.....	364.00	1 m.g.d.
PENNSYLVANIA.						
Media	33.	29.9	25.	10.10	173.30	Partially developed, 1.5 m.g.d.
Crum Lynn, Crum Creek	34.9	29.5	13.5	8.50	130.00	
Springfield, Crum Creek	31.9	29.5	10.	33.90	500.00	2 m.g.d.
VERMONT.						
Barre	42.	2.7	8.0	13.90		
"	42.	2.7	12.3	40.80		
"	42.	2.7	14.7	27.70		
"	42.	2.7	22.6	18.00		
Total, excluding figures in parentheses and giving multiplied weight to average figures for several privileges (each owned, perhaps, by several mills)				$9 606.89		
Average (of 125 " Developed Privileges, by Award ")				**$76.85**		

* Two privileges.

SUMMARY OF DEVELOPED PRIVILEGES.

By Agreement.

Location.	Watershed. Square Miles. Total.	Watershed. Square Miles. Diverted.	Available all. Feet.	Price (Excluding Interest), etc. Per Square Mile per Foot of Fall.	Price (Excluding Interest), etc. Per Million Gallons Daily per Foot of Fall.	Remarks.
CONNECTICUT.						
Cheshire, Ten Mile River	73.5	1.6	6.9	$54.40		
” ” ” ”	7.3	1.6	9.8	63.80		
East Lyme, Great Brook	16.5	6.4	9.8	23.90		
” ” ” ”	16.4	6.4	11.7	52.90		
” ” ” ”	10.4	6.4	20.	46.60		
Killingly, Whetstone Brook	14.9	0.4	15.	36.20		
” ” ”	15.0	0.4	26.	35.70		
Meriden and Wallingford, 6 privileges on Quinnipiac River	92.1	1.6	18.	52.90	....	6 privileges.
	94.4	1.6	8.			
	96.	1.6	7.1			
	100.4	1.6	5.9			
	106.4	1.6	8.			
	106.5	1.6	6.25			
Montville, Great Brook	6.4	6.4	10.	(108.60)	....	Includes mill.
Norwich, Yantic River	93.	1.5	71.	47.00		
” Hammer Brook	2.5	1.5	Unknown.	.....	....	Special case.
” Ice Pond	0.6	0.3	5.	.....	....	Special case.
Plainfield, Mill Brook	20.	0.9	47.	37.80		
Southington, Ten Mile River	16.6	1.6	5.7	54.80		
Thompson, French River	94.	94.	1.5	53.20		
Wallingford, Quinipiac River	110.5	1.6	6.9	181.20		
Waterbury, Naugatuck River	21.	18.	12.	13.90		
Waterford, Beaver Dam Brook	8.8	0.6	33.	147.00		
” ” ” ”	8.8	0.6	20.	48.40		
MASSACHUSETTS.						
Andover, Merrimac River	....	2.7	30.	14.80		
Billerica, ” ”	352.	75.2	11.	87.50		

Summary of Developed Privileges.

(Continued.)

By Agreement.

Location.	Watershed. Square Miles. Total.	Watershed. Square Miles. Diverted.	Available Fall. Feet.	Price (Excluding Interest), etc. Per Square Mile per Foot of Fall.	Price (Excluding Interest), etc. Per Million Gallons Daily per Foot of Fall.	Remarks.
Clinton, Wachusett Reservoir	113.4	113.4	15.5	$35.20		
,, ,, ,,	118.3	118.3	28.	87.30		
Framingham, Sudbury River	100.0	75.2	26.	67.20		
Groton	428.5	118.3	8.	37.00		
Lancaster and Clinton, Nashua River	128.8	118.2	8.	37.00		
Lawrence, Merrimac River	4 599.	118.2	32.5	22.62	....	Essex Company.
,, ,, ,,	4 599.	75.2	32.	10.90		
Lowell, Concord River	370.	75.2	24.8	70.90	....	8 Mills on one privilege.
,, ,, ,,	375.	75.2	8.	28.80		
,, ,, ,,	380.	75.2	11.3	41.10		
,, Merrimac ,,	4 085.	118.2	39.	25.15	....	Locks and Canals [Company.
Middleboro, Assawompsett Pond	59.	12.8	13.5	37.50		
Oakdale, Nashua River	94.8	94.8	27.	35.15		
,, Quinepoxet River	53.8	53.8	22.8	24.30		
,, ,, ,,	54.2	54.2	16.8			
Springfield, Chicopee River	*	8.1	33.	21.10		
,, ,, ,,	*	8.1	28.	19.60		
,, ,, ,,	*	8.1	33.	7.20		
,, ,, ,,	*	8.1	43.	2.80		
,, ,, ,,	*	8.1	13 5	17.30		
Wellesley, Charles River	.....	....	.....	92.14		
West Boylston, Nashua River	98.3	98.3	11.	20.70		
,, ,, ,,	98.3	98.3	11.	20.70		
,, ,, ,,	98.9	98.9	18.4	29.10		
Maryland.						
Baltimore, Yantic River	280.	....	10.	.....	$100.00	Up to 150 m.g.d.

* Several hundred square miles.

New Hampshire.						
Ashland, Winnepesaukee Lake, 2 mills	56.7	56.7	29.	(6.08)	....	Including bldgs. In 1888.
Brist l, "	91.	91.	46(?)	(3.58)	....	In 1884.
Nashua, Nashua River	522.0 506.1 527.3	118.2 118.2 118.2	35.3 11.0 22.3	33.60 58.00	....	3 privileges.
Tilton, Laconia, and Guilford, on Lake Winnepesaukee	366. 428.	366. 428.	16. 12.	6.75	....	In 1889.
Wolfboro	24.	24.	18.	13.87	....	In 1889.
New York.						
Brunswick, Quackenkill River	25.3	17.5	3.	52.38		
Troy, Poestenkill Creek	96.	17.5	12.	23.80		
Pennsylvania.						
Bradford	104.	14.	9.5	(112.80)	....	Including mill. 1.5 m.g.d.
Springfield, Crum Creek	25.	25.	10.	20.00		
Rhode Island.						
Woonsocket, Blackstone River	472.	7.9	174.9	137.00	....	Average. 6 privileges.

Total, exclusive of amounts shown in parenthesis, *giving multiplied weight to average records* for several privileges, each owned, perhaps, by several mills $3 171.26

Average (of 60 " Developed Privileges by Agreement "), $52.85

Average of 185 " Developed Privileges by Award and by Agreement " $69.07

SUMMARY OF UNDEVELOPED, ABANDONED, OR UNUSED PRIVILEGES.

By Award.

Location.	Watershed. Square Miles. Total.	Watershed. Square Miles. Diverted.	Available. Fall. Feet.	Price (Excluding Interest), etc. Per Square Mile per Foot of Fall.	Price (Excluding Interest), etc. Per Million Gallons Daily per Foot Fall.	Remarks.
CONNECTICUT.						
Killingly, Whetstone Brook	14.8	0.4	12.	$12.80		
Putnam, Little River	40.8	...	33.	.....	$136.00	500 000 g.p.d.
MASSACHUSETTS.						
Avon, Porter's Spring	...	...	.....	.....	.....	$52 600 per m.g.d., about 90 000 g.p.d.
Gloucester, Lily Pond	...	...	.....	.....	.....	$25 600 per m.g.d., about 780 000 g.p.d.
Waltham, Stony Brook	21.5	21.5	29.6	$15.72	.....	Practically an abandoned privilege.
Westfield, Little River	21.	6.4	10.	6.98		
NEW HAMPSHIRE.						
Nashua, Nashua River	528.	118.2	.....	.....	.....	Special damage.
NEW YORK.						
Ithaca, Taughannock River	67.	67.	543.	2.21		
Rome, Fish Creek	135.	..	273.	0.20		
Schaghticoke, Tomhannock Creek	69.	67.	18.	*	.....	Unused privilege.
" " "	75.	67.	150.	2.19		
" " "	78.	67.	40.	5.97		
" " "	80.	67.	8.	2.24		
PENNSYLVANIA.						
Springfield, Crum Creek	33.7	21.9	11.	11.20	123.00	Abandoned privilege.
VERMONT.						
Barre	42.	2.7	28.3	11.80		
Average (of 10 "Undeveloped Privileges by Award")				$7.13		

* Included with No. 166.

By Agreement.

CONNECTICUT.						
Cheshire, Ten Mile River	6.3	1.6	16.	5.86		
East Lyme, Great Brook	16.4	6.4	9.5	19.60		
” ” ” ”	16.4	6.4	9.1	25.60		
” ” ” ”	14.2	6.4	11.	8.50		
MAINE.						
Tributary to Kennebec	200.	200.	38.	1.71		
” ” ”	200.	200.	48.	2.50		
NEW HAMPSHIRE	3 000.		20.	4.70		
NEW YORK.						
Brunswick, Quackenkill River	91.3	17.5	55.1	6.23		
” ” ”	91.3	17.5	10.6	5.40		
” ” ”	18.1	17.5	74.	1.04		
PENNSYLVANIA.						
Springfield, Crum Creek	33.7	29.5	14.	8.48	125.00	Abandoned privilege.

Average (of 11 “ Undeveloped Privileges by Agreement ”) . . . $8.15

Average (of 21 “ Undeveloped Privileges by Award and by Agreement ”), $7.66

APPENDIX B.

FUNDAMENTAL DATA RECEIVED BY COMMITTEE.

1 Connecticut, Cheshire, New Haven County, 1909.

New Haven Water Company and Cheshire Brass Company.

DEVELOPED WATER PRIVILEGE ON TEN MILE BROOK.

Authority: C. E. Chandler, Norwich, Conn., and A. B. Hill, New Haven.

BY AWARD, $7 000.

Watershed above privilege: 5.6 square miles.

Watershed taken: 1.6 square miles.

Fall: 22 feet.

Fall developed: 22 feet.

12 hour power.

Character of development: dams, canals, etc. Product of mill is brass plate.

Character of watershed: partly mountainous and partly glacial drift.

Coal: $4.50 per ton.

A small amount of water is used for other purposes than power.

One 50 HP. wheel installed.

150 HP. of steam.

100 to 200 HP. required to run mill.

150 HP. supplementary power necessary.

Area of mill pond, 4 000 square feet.

Working depth of mill pond, 1 foot.

1 storage reservoir upon watershed of 1 800 000 cubic feet.

Full control.

Controlling factor in the award: market value of the property.

The existence of a relatively large storage reservoir in full control of the mill owner made the diverted water theoretically unusually valuable. Mill owner claimed an underground drainage area much greater than surface drainage area. Brass Company's engineers claimed average diverted power 19½ HP. Water Company's engineer claimed 7 HP. Brass Company's engineer claimed damage $23 450. Water Company's engineer claimed not over $5 000.

$198.86 PER SQUARE MILE PER FOOT OF FALL.

2 Connecticut, Cheshire, New Haven County, 1909.

New Haven Water Company and John O. Shares.

DEVELOPED WATER PRIVILEGE ON TEN MILE BROOK.

Authority: C. E. Chandler, Norwich, Conn., and A. B. Hill, New Haven, Conn.

BY AWARD, $1 500.

Watershed above privilege: 5.7 square miles.

Watershed taken: 1.6 square miles.

Fall: 20 feet.

Fall developed: 19.4 feet.

Power not in use at time of trial but had been in use ten hours per day.

Character of development: dam, races, etc., and shop for making hardware.

Character of watershed: partly mountainous and partly glacial drift.

No steam used. Water for power only.

Number of wheels installed: one 35 HP.

Power required to run mill: variable.

Area of mill pond: $\frac{1}{4}$ of an acre.

Storage reservoirs upon watershed: one, containing 1 800 000 cubic feet.

Controlling factors in the award: relative market value of the property before and after taking.

Practically the ownership of this power was identical with that of the Cheshire Brass Mill, and this owner had the benefit of the storage and pondage above. Technically the ownership was separate and this owner had no rights therein. John O. Shares claimed his intention was to use it in connection with the Cheshire Brass Mill by the aid of electricity, and his engineer claimed about $21 000 damages. The Water Company's engineers claimed that the damage did not exceed $1 300 to $1 500 for practical reasons as to market value and theoretical reasons as to storage and pondage.

$46.87 per Square Mile per Foot of Fall.

3 Connecticut, Cheshire, 1908.

George C. McKenzie *v.* New Haven Water Company.

DEVELOPED WATER PRIVILEGE ON TEN MILE RIVER.

Authority: A. B. Hill, New Haven, Conn.

BY AGREEMENT, $600.

Grist and saw mill.

Watershed taken: 1.6 out of 73.5 square miles.

Fall used: 6.9 feet.

10 hour power.

Character of watershed: broad, sandy valley between high, rocky hills.
No auxiliary power. Water for power only.
4 wheels installed, 8.4, 5.6, 12.5, and 48.2 HP.
Mill pond: 500 000 cubic feet.
Usable power diverted (at 75 per cent. efficiency): 0.37 HP.

$54.40 PER SQUARE MILE PER FOOT OF FALL.

4 Connecticut, Cheshire, 1908.

Jane E. Warner *v.* New Haven Water Company.

UNDEVELOPED WATER PRIVILEGE ON TEN MILE RIVER.

Authority: A. B. Hill, New Haven, Conn.

BY AGREEMENT, $150.

Cider and saw mill.
Watershed taken: 1.6 out of 6.3 square miles.
Diversion: 0.69 HP. (at 75 per cent. efficiency).
Fall used: 16 feet.
Character of watershed: narrow valley with steep side slopes.
One 10 HP. wheel installed. No auxiliary power.
Water for power only. No pondage.

$5.86 PER SQUARE MILE PER FOOT OF FALL.

5 Connecticut, Cheshire, 1908.

Joseph P. Moss *v.* New Haven Water Company.

DEVELOPED WATER PRIVILEGE ON TEN MILE RIVER.

Authority: A. B. Hill, New Haven, Conn.

BY AGREEMENT, $1 000 (exclusive of interest).

Saw, grist, and wood turning mill.
Watershed taken: 1.6 out of 7.3 square miles.
Fall used: 9.8 feet.
Character of watershed: narrow valley with steep side slopes.
2 wheels, 20 HP. each. No auxiliary power. Water for power only.
Pondage: 300 000 cubic feet.
Usable power diverted (at 75 per cent. efficiency): 3.02 H.P. Power used about one-half time only.

$63.80 PER SQUARE MILE PER FOOT OF FALL.

6 Connecticut, East Lyme, 1901.

Fred G. Hall *v.* New London.

DEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $1 500.

Watershed diverted: 6.44 square miles out of 16.5 square miles.
Theoretical fall: 9.75 feet.
Turning mill.
Watershed: rolling and hilly.
Approximate area of mill pond: 2 acres.

$23.90 PER SQUARE MILE PER FOOT OF FALL.

7 Connecticut, East Lyme, 1901.
Comstock Heirs *v.* City of New London.

UNDEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $1 200.

Watershed diverted: 6.44 square miles out of 16.4 square miles.
Theoretical fall: 9.5 feet.
Watershed: rolling and hilly.

$19.60 PER SQUARE MILE PER FOOT OF FALL.

8 Connecticut, East Lyme, 1901.
Luce Bros. *v.* City of New London.

UNDEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $1 500.

Watershed diverted: 6.44 square miles out of 16.4 square miles.
Theoretical fall: 9.1 feet.
Watershed: rolling and hilly.
Award includes mill site, etc.

$25.60 PER SQUARE MILE PER FOOT OF FALL.

9 Connecticut, East Lyme, 1908.
William G. Sharpe *v.* City of New London.

UNDEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $600.

Watershed diverted: 6.44 square miles out of 14.2 square miles.
Theoretical fall: 11 feet.
Watershed: rolling.

$8.50 PER SQUARE MILE PER FOOT OF FALL.

10 Connecticut, East Lyme, 1901.

Albert R. Darrow *v.* City of New London.

DEVELOPED PRIVILEGE (NOT IN USE) ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $4 000.

Watershed diverted: 6.44 square miles out of 16.36 square miles.
Theoretical fall: 11.75 feet.
Watershed: rolling and hilly.
Area of mill pond: about 3 or 4 acres.
One small storage reservoir upon watershed.

$52.90 PER SQUARE MILE PER FOOT OF FALL.

11 Connecticut, East Lyme, 1901.

George Lattimer *v.* City of New London.

DEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $6 000.

Watershed diverted: 6.44 out of 10.44 square miles.
Theoretical fall: about 20 feet.
Watershed: rolling and hilly.
Grist mill.
Area of mill pond: less than 1 acre.

$46.60 PER SQUARE MILE PER FOOT OF FALL.

12 Connecticut, Killingly, 1886.

Sabin L. Sayles *v.* Crystal Water Company of Danielson.

DEVELOPED PRIVILEGE ON WHETSTONE BROOK.

Authority: William Wheeler, Boston, Mass.

BY SALE OR AGREEMENT, $234.

Watershed taken: 0.43 square miles out of 14.95 square miles.
Fall: about 15 feet.
10 hour power.
Character of development: woolen mill.
Character of watershed: wood land and pasture.
Steam is used for manufacturing or other purposes.
Approximate area of mill pond: very small.
Storage reservoirs of relatively small capacity upon the watershed.
Character of control: dam and sluice gates.
Award did not include any allowances other than for the water or water power.

$36.20 PER SQUARE MILE PER FOOT OF FALL.

13 Connecticut, Killingly, 1886.

Sabin L. Sayles (Hopkins, Lessee) *v.* Crystal Water Company of Danielson.

DEVELOPED MILL PRIVILEGE ON WHETSTONE BROOK.

Authority: William Wheeler, Boston, Mass.

BY SALE OR AGREEMENT, $400.

Watershed taken: 0.43 square miles out of 15 square miles.

Fall: about 26 feet.

10 hour power.

Character of development: woolen mill.

Character of watershed: woodland and pasture.

Steam is used for manufacturing or other purposes.

Approximate area of mill pond: small.

Relatively small storage areas upon watershed.

Character of control: dam with sluice gates.

Award did not include any allowances other than for the water or water power.

$35.70 PER SQUARE MILE PER FOOT OF FALL.

14 Connecticut, Killingly, 1888.

F. P. Warren *v.* Crystal Water Company of Danielson.

DISMANTLED AND ABANDONED WATER PRIVILEGE ON WHETSTONE BROOK.

Authority: William Wheeler, Boston, Mass.

BY SALE OR AGREEMENT, $66.

Watershed taken: 0.43 square miles out of 14.75 square miles.

Fall: 12 feet.

Character of watershed: woodland and pasture.

Controlling factors in award: 12 feet of fall (dismantled) at $5.50 per foot.

In addition to the stated sum of $66, the sum of $234 was paid for land and to reimburse the seller for estimated cost of building a cattle-pass.

$12.80 PER SQUARE MILE PER FOOT OF FALL.

15 Connecticut, Meriden and Wallingford, 1908.

Meriden Cutlery Company, Jennings & Griffin, The Charles Parker Company, C. I. Yale Manufacturing Company, International Silver Company, R. Wallace & Sons Manufacturing Company *v.* New Haven Water Company.

DEVELOPED PRIVILEGE ON QUINNIPIAC RIVER.

Authority: A. B. Hill, New Haven, Conn.

BY AGREEMENT, $4 500 for six mills. Distribution unknown.

Watersheds above privileges: 92.1, 94.4, 96.0, 100.4, 106.4, and 106.5 square miles respectively.

Watershed taken: 1.6 square miles.

Fall used: 18, 8, 7.1, 5.9, 8, and 6.25 feet respectively. Total, 53.25 feet.

10 hour power.

Character of water shed: broad, sandy valley between high, rocky hills.

Water used for other purposes than power: no, yes, no, yes, no, no.

Number of wheels installed: 1, 2, 3, 1, 2, 2, respectively.

Power of wheels: 152, (90 and 65), (75, 75, and 50), 96, (100 and 100), (47 and 47).

Amount of steam or electricity necessary: none, 165 HP., 100 HP., 60 HP., 60 HP., 450 HP.

Working capacity of mill pond: 5 200 000, 350 000, 75 000, 100 000, 8 750 000, 260 000 cubic feet.

Usable power diverted (75 per cent. efficiency): 0.6 HP., 0.93 HP., 1.32 HP., 0.53 HP., 0.64 HP., 0.32 HP.

Small amount of water used for mill purposes by Jennings & Griffin, also by C. I. Yale Manufacturing Company.

Power used for (1) cutlery; (2) mechanic tools; (3) wood working; (4) edged tools, hardware, and spoons; (5 and 6) silverware.

$52.90 PER SQUARE MILE PER FOOT OF FALL.

16 Connecticut, Montville, 1901.

Joseph M. Beckwith *v.* City of New London.

DEVELOPED PRIVILEGE ON GREAT BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $7 000.

Watershed diverted: 6.44 out of 6.44 square miles.

Saw mill (small).

Theoretical fall: about 10 feet.

Watershed: hilly.

Approximate area of mill pond: about 2 acres.

Allowance included mill.

$108.60 PER SQUARE MILE PER FOOT OF FALL, INCLUDING MILL.

17 Connecticut, Naugatuck, New Haven County, about 1890.

The Naugatuck Water Company and the Connecticut Rubber Company.

DEVELOPED WATER PRIVILEGE ON STRAITSVILLE BROOK.

Authority: C. E. Chandler, Norwich, Conn.

BY AWARD, $150.

Watershed above privilege: 20 square miles.

Watershed diverted: 1.75 square miles.

Fall taken: 35 feet.

Fall used: 20 feet.

Character of development: consisted of a dam, a water wheel, and a tailrace. Mill in which rubber had been manufactured had been burned.

Character of watershed: rather steep.

Water has been used for other purposes than power.

One wheel installed, 25 HP.

To improve privilege, dam must be raised and tailrace deepened; cost not estimated.

Estimated area of mill pond: very small.

Controlling factors in award: estimated value of property in its unused condition and relative proportion of water diverted to whole flow.

Arbitrators were three farmers. The water company made gagings of the stream at diversion point June 20 and 30, 1888, that showed an average flow of 650 000 gallons daily, including one storm. The stream at mill site gave a flow about eight times as large. Rubber Company claimed the diversion equal to 4 HP. in five summer months, and that it would cost $100 per year to replace it with steam, which capitalized at 5 per cent., made the damage $2 000. Water Company claimed the damage could not exceed one eighth of market value of the real estate, say $100.

$2.45 PER SQUARE MILE PER FOOT OF FALL.

18 Connecticut, New London, 1897.

W. R. Perry *v.* City of New London.

DEVELOPED PRIVILEGE ON BRIGGS BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AWARD, $8 000.

Watershed diverted: 1.64 out of 2 square miles.

Theoretical fall: 51 feet.

Watershed: rolling.

No storage reservoirs upon watershed.

Controlling factor in award: alleged value of stream for an ice privilege.

Award included land for dam site and pipe line right.

City's engineers claimed that there would be sufficient water for ice pond after diversion, and that 15 HP. was liberal rating of power development.

Perry's engineers claimed 25 HP. and that its market value undeveloped was \$25 000 to \$31 000.

\$95.60 PER SQUARE MILE PER FOOT OF FALL, INCLUDING PIPE LINE RIGHT.

19 Connecticut, New London, 1897.

Rogers Bros. *v.* City of New London.

DEVELOPED PRIVILEGE ON BRIGGS BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AWARD, \$4 000.

Watershed diverted: 1.64 out of 2.4 square miles.

Ice pond.

Theoretical fall: slight.

No developed fall.

Watershed: rolling.

No storage reservoirs upon watershed.

Controlling factor in award: damage to ice privilege.

City's engineers claimed that the 245 acres of remaining watershed would supply Rogers 3 000 000 gallon ice pond, and consequently damage was nominal. They showed that four ice ponds in constant use in Norwich had only from 15 to 55 acres per million gallons pondage. Rogers' engineers claimed that a steam plant could be built on the Rogers' land, and that he should be paid the capitalized value of the coal saved by using the diverted water for condensing.

SPECIAL.

20 Connecticut, Norwich, New London County, 1894.

Falls Company *v.* Board of Water Commissioners of Norwich.

DEVELOPED WATER PRIVILEGES ON YANTIC RIVER.

Authority: C. E. Chandler, Norwich.

SALE, \$5 000 (exclusive of interest).

Watershed diverted: 1.5 square miles out of 93 square miles.

Fall: 71 feet.

10 hour power.

Character of development: two good dams with 51 and 20 feet fall respectively.

Cotton mill at former and a file shop at latter with races, bulkheads, etc.

Watershed: ordinary, rolling.

Coal: \$4.50 per short ton.

Steam used to some extent.

Moderate amount of water used for dyeing.

Four wheels, one of 500 HP. and one pair 250 HP. each on the 51 foot fall and one about 150 HP. on the 20 foot fall.

Total power required to run mill: 800 HP. at the 51 foot fall and 100 HP. extra for lights.

Supplementary steam or electricity used: 900 HP.

A full development at upper dam would include another and larger wheel and mill to use the power.

Area of mill ponds at the 51 foot fall, say $\frac{1}{4}$ acre; at the 20 foot fall, perhaps 5 acres.

Working depth of mill pond: the larger pond is usually emptied when necessary to save water.

Storage reservoirs upon watershed: one of 614 acres which can be drawn 7.4 feet in depth.

Complete control of storage by the company.

The price paid was the asking and only price for which the right could be obtained without a suit at law.

$47 PER SQUARE MILE PER FOOT OF FALL.

21 Connecticut, Norwich, New London County, 1881.

Board of Water Commissioners of the City of Norwich and S. B. Case.

DEVELOPED WATER PRIVILEGE ON HAMMER BROOK.

Authority: C. E. Chandler, Norwich, Conn.

SALE, $5 000 (exclusive of interest).

Tannery.

Watershed above privilege: 2.5 square miles.

Watershed diverted: 1.5 square miles.

Character of development: slight dam with vats, etc., for tanning leather.

Character of watershed: ordinary rolling.

Wholly used in tanning leather.

The property as a tannery had a very small value and was but little used after the sale.

$3 333 PER SQUARE MILE (for water, not power).

22 Connecticut, Norwich, New London County, 1894.

Ponemah Mills and Simeon Lord.

WATER USED FOR ICE POND, BUT PRACTICALLY NO POWER.

Authority: C. E. Chandler, Norwich, Conn.

BY AWARD, $1. (See remarks below.) LATER PURCHASE, $800.

Watershed above privilege: $\frac{5}{8}$ square mile.

Watershed diverted: $\frac{1}{4}$ square mile.

Fall used: 5 feet.

Character of development: dam for ice purposes and hydraulic ram.

Character of watershed: ordinary rolling.

A manufacturing company, having no right of eminent domain to build a reservoir, built a reservoir to supply water to its village. The owner of a saloon had on the same stream below an ice pond and a hydraulic ram pumping water for his saloon and residence over it. The saloon keeper brought suit for \$6 000 damages, claiming that his ice pond and water supply was injured. The manufacturing company's engineer claimed that whenever there was or would have been, any water flowing at the diverting point, there would be an ample supply for the ice pond and hydraulic ram where they were located, and hence damage was merely nominal. Damages awarded, \$1. Later the right to divert was purchased for \$800.

NOMINAL AWARD, \$1.

LATER PURCHASE, \$640 (?) PER SQUARE MILE PER FOOT OF FALL OR $\frac{800}{0.25}$ = \$3 200 PER SQUARE MILE DIVERTED.

23 Connecticut, Plainville, Hartford County.

Hills Novelty Company and George W. Eaton *v.* City of New Britain.

DEVELOPED PRIVILEGE ON PLAINVILLE POND, PEQUABUCK RIVER.

Authority: Arthur T. Safford, Lowell, Mass.

BY AWARD, \$6 500.

Watershed diverted: 7.15 square miles out of 46.4. All the water of the North Branch, so called.

Developed fall: 14.0 feet out of 15.07 feet.

11 hour power usually.

A wooden dam across Pequabuck River at the lower end of Plainville pond of 100 acres; power used on one side for making wood and metal novelties; on other side for grist mill.

Watershed: wooded and steep, elevation 1 000 feet and less, flat meadows and some swamp.

Steam is also used for heating at Hills Novelty Company; none at grist mill.

Water is used for sanitary purposes.

Two wheels installed: Novelty Company, 44 HP.; grist mill, 70 HP.

To improve privilege: raise dam.

Approximate area of mill pond: 100 acres.

Approximate depth to which mill pond can be drawn: 1 to 2 feet.

Five storage reservoirs upon watershed of about 43 000 000 cubic feet capacity, but drawn down and diverted already for water supply purposes; only overflow gets into stream; also two others of about 22 000 000 cubic feet.

First five controlled by water company; other two by concerns on small streams on which these reservoirs are located.

Controlling factors in award: loss of a little less than 8 HP. for eight months in the year from the stream where the storage in the mill pond at the dam was sufficient to take care of the night flow for the eight lowest months in the year.

Award did not include any allowances other than for water or water power.

A settlement was made by the owners from the engineer's reports before the diversion was actually made. This power is a good type of a small water power which has been used for a great many years and which with others has built up the small industries of Connecticut. This property has never been idle as far as I know.

$65 PER SQUARE MILE PER FOOT OF FALL.

24 Connecticut, Plainfield, Windham County, 1895.

Jewett City Water Company and Packer Manufacturing Company.

DEVELOPED WATER PRIVILEGE ON MILL BROOK.

Authority: C. E. Chandler, Norwich, Conn.

SALE, $1 600 (exclusive of interest).

Watershed above privilege: 20 square miles.

Watershed taken: $\frac{9}{10}$ square mile.

Fall: 47 feet.

Fall used: 19 feet fully developed, 20 feet partly developed and partly abandoned, 8 feet undeveloped.

10 hour power.

Character of development: dams, races, and so forth for making cloth, grinding grain, and sawing lumber.

Character of watershed: ordinary rolling.

Steam not used. Water used for power only.

Number of wheels installed: two 72 HP.

To improve the privilege: must put in expensive penstocks.

No storage reservoirs.

The arbitrator chosen by Packer Company claimed damage of $100 per foot mile, or $3 680, based on 40 foot fall, 0.92 square miles diverted, on the theory that this was about an average of a number of sales or awards in New Britain and other places. The arbitrator chosen by the Water Company claimed that, on account of the partial abandonment of the power and the abandonment of

many small powers in the vicinity, the damage to the market value was but little more than nominal.

$37.80 PER SQUARE MILE PER FOOT OF FALL.

25 Connecticut, Putnam, Windham County, 1895.

Putnam Water Company and George M. Morse.

UNDEVELOPED WATER PRIVILEGE ON LITTLE RIVER.

Authority: C. E. Chandler, Norwich, Conn.

BY AWARD, $2 250.

Watershed above privilege: 40.75 square miles.

Water diverted: 500 000 gallons daily.

Fall: 33 feet. None used.

Character of watershed: hilly but not mountainous.

Coal: $4.50 per ton.

To improve privilege: complete development and additional land and flowage rights.

Storage reservoirs upon watershed: Woodstock Lake, 86 acres. A natural lake without dam or gates.

The award was made by a committee consisting of a lawyer, a civil engineer, and a manufacturer. Mr. Morse's engineers claimed:

1. 500 000 gallons daily, with net fall of 30 feet, which would give 4.735 HP., for which he should be paid eight months in the year.

2. Each HP. should be valued at $50 per year, or $157.83⅓ for 4.735 HP. for eight months, which should be capitalized at 4 per cent., making $3 945.83.

Putnam Water Company's engineers claimed:

1. That this was absurd because at the same rate the 375 HP. which Mr. Morse's engineer claimed was minimum power would be worth undeveloped $218 000.

2. That $50 per HP. was wrong, because Mr. Morse's engineers said the same steam plant would be put in whether or not the diversion was made, and hence the cost of coal only should be considered, or $58.60 per annum.

3. That the capitalization should be 10 per cent. instead of 4 per cent.

4. That the privilege was not worth development and acquiring necessary additional land and rights.

5. That steam power could be developed for $22 per annum with a 500 HP. plant.

6. That it was a mile or more from a railroad and many miles from seaboard.

7. That, in view of all the above conditions, the market value of the land was not affected by the taking.

$4 500 PER MILLION GALLONS DIVERTED (undeveloped privilege),
or $136 PER MILLION GALLONS DAILY PER FOOT OF FALL.

26 Connecticut, Southington, 1908(?).
F. L. Ellis & Son *v.* New Haven Water Company.
DEVELOPED WATER PRIVILEGE ON TEN MILE RIVER.
Authority: A. B. Hill, New Haven, Conn.
BY AGREEMENT, $500.
Builders' hardware.
Watershed taken: 1.6 out of 16.6 square miles.
Fall used: 5.7 feet.
10 hour power.
Character of watershed: narrow valley with steep side slopes.
Water used for power only.
One 14.5 HP. wheel installed.
Supplementary power necessary: 15 HP.
Mill pond: 150 000 cubic feet.
Usable power diverted (at 75 per cent. efficiency): 0.29 HP.
$54.80 PER SQUARE MILE PER FOOT OF FALL.

27 Connecticut, Thompson, Windham County, about 1870.
Grosvenordale Company and Oscar F. Chase.
DEVELOPED WATER PRIVILEGE ON FRENCH RIVER.
Authority: C. E. Chandler, Norwich, Conn.
SALE, $7 500 (exclusive of interest).
Watershed above privilege: 94 square miles.
Fall taken: 1½ feet of fall sold by Chase, the upper owner, to Grosvenordale Company, the lower owner.
10 hour power.
Full development for making cotton cloth.
Character of watershed: ordinary rolling.
This fall was probably available for the purchaser by the use of a flashboard at nominal cost for development and possibly it would have cost the seller a good deal to make it available for him.
$53.20 PER SQUARE MILE PER FOOT OF FALL.

28 Connecticut, Wallingford, 1908(?).
Borough of Wallingford *v.* New Haven Water Company.
DEVELOPED WATER PRIVILEGE ON QUINNIPIAC RIVER.
Authority: A. B. Hill, New Haven, Conn.

BY AGREEMENT, $2 000 (exclusive of interest).

Operated as auxiliary to steam electric light and power station.

Watershed above privilege: 110.5 square miles.

Watershed diverted: 1.6 square miles.

Fall used: 6.9 feet.

Character of development: electric light station.

Character of watershed: broad, sandy valley between high, rocky hills.

Steam is used for other purposes.

4 wheels: 25, 25, 35, and 100 HP.

Working capacity of mill pond: 500 000 cubic feet.

Usable power: 0.8 HP. (at 75 per cent. efficiency).

$181.20 PER SQUARE MILE PER FOOT OF FALL.

29 Connecticut, Waterbury.

James Roberts *v.* City of Waterbury.

DEVELOPED WATER PRIVILEGE ON WEST BRANCH, NAUGATUCK RIVER.

Authority: R. A. Cairns, Waterbury, Conn.

BY AWARD, $2 000.

Character of privilege: grist mill.

Watershed above privilege: 20 square miles.

Watershed diverted: 18 square miles.

Developed fall: 7 feet.

$15.90 PER SQUARE MILE PER FOOT OF FALL.

30 Connecticut, Waterbury.

Joseph Newell *v.* City of Waterbury (?).

DEVELOPED WATER PRIVILEGE ON WEST BRANCH OF NAUGATUCK RIVER.

Authority: R. A. Cairns, Waterbury, Conn.

BY AGREEMENT, $3 000.

Saw mill.

Area of watershed above privilege: 21 square miles.

Area of watershed diverted: 18 square miles.

Fall used: 12 feet.

$13.90 PER SQUARE MILE PER FOOT OF FALL.

31 Connecticut, Waterbury.

American Knife Company *v.* City of Waterbury.

DEVELOPED WATER PRIVILEGE ON WEST BRANCH OF NAUGATUCK RIVER.

Authority: R. A. Cairns, Waterbury, Conn.

BY AWARD, $7 000.

Character of privilege: factory for pocket cutlery.
Watershed above privilege: 23 square miles.
Watershed diverted: 18 square miles.
Developed fall: 13 feet.

$29.90 PER SQUARE MILE PER FOOT OF FALL.

32 Connecticut, Waterbury.
Henry Reynolds *v.* City of Waterbury.

DEVELOPED WATER PRIVILEGE.

Authority: R. A. Cairns, Waterbury, Conn.

BY AWARD, $1 200.

Character of privilege: saw mill.
Watershed above privilege: 23.2 square miles.
Watershed diverted: 18 square miles.
Developed fall: 7 feet.

$9.52 PER SQUARE MILE PER FOOT OF FALL.

33 Connecticut, Waterford, 1894.
Robertson Bros. *v.* City of New London.

DEVELOPED PRIVILEGE ON BEAVER DAM BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $3 000.

Watershed diverted: 0.62 square miles out of 8.75.
Paper mill.
Theoretical fall: 33 feet.
Watershed: partly steep and partly swampy.
Water is used for paper making.
One rather large storage reservoir on watershed.

$147 PER SQUARE MILE PER FOOT OF FALL.

34 Connecticut, Waterford, 1894.
Oliver Woodworth *v.* City of New London.

DEVELOPED PRIVILEGE ON BEAVER DAM BROOK.

Authority: W. H. Richards, New London, and C. E. Chandler, Norwich, Conn.

BY AGREEMENT, $600.

Watershed diverted: 0.62 out of 8.75 square miles.
Paper mill.
Developed fall: 20 feet out of 20 feet.
24 hour power.

Watershed: partly steep and partly swampy.

Water is used for paper making.

One large storage reservoir upon watershed.

$48.40 PER SQUARE MILE PER FOOT OF FALL.

35 Connecticut, Wilton, 1903 and 1904.

City of South Norwalk, Norwalk Mills Company, Lounsbury-Bissell Company, Wm. F. Bishop, Mrs. Merwin.

DEVELOPED WATER PRIVILEGE.

Authority: Stephen S. Hatch, South Norwalk, Conn.

BY AWARD, $16 000 (approximate) for mill damages and water rights.

Character of privilege: permanent for all water that can be stopped.

Area of watershed above privilege: approximately 7 square miles.

Water diverted: with use of a 7-foot dam we get 7 500 000 gallons daily, when pipe is well covered.

This does not include watershed obtained in 1875. System is all gravity.

36 Connecticut, Windsor, Hartford County, 1907.

The Windsor Water Company, Charles F. Lewis (hereafter referred to as No. 1), L. L. Bedortha (hereafter referred to as No. 2).

DEVELOPED WATER PRIVILEGE ON MILL BROOK.

Authority: N. W. Hayden, Windsor, Conn.

BY AWARD, $2 675. The further agreement to allow the owner of the water privilege to connect at his own expense with one 6-inch main and install a hydrant, which he is to have free use of for twenty years for fire protection only.

Character of privilege: No. 1, grist and saw mill; No. 2, wood-working mill.

Watershed above privilege: 1 square mile above No. 1; practically nothing between No. 1 and No. 2.

Watershed taken: partially from 1 square mile.

Water taken: 200 000 gallons per twenty-four hours.

Fall: No. 1, 20 feet; No. 2, 9.8 feet.

Fall used: No. 1, 18.9 feet; No. 2, 8 feet.

8 hour power.

Character of development: No. 1, a country grist mill; No. 2, cigar bands, levels.

Character of watershed: woodland and pasture, sandy soil, not steep.

Coal: $5 per 2 000 pounds.

Steam is used in No. 1; No. 2, gasoline and producer gas.

Two wheels installed: No. 1 claimed 20 HP.; No. 2 claimed 9 HP.

Steam development: 40 HP.

Supplementary steam or electricity required: No. 1, extreme low water or when running saw mill, 20 HP.; No. 2, yes.

To improve privilege: No. 1, a new pond for which there is a good chance to give storage capacity at cost of $1 500, approximately; No. 2, fully developed.

Area of mill pond: a survey of pond of No. 1 showed area of 72 640 square feet.

Working depth of mill pond: No. 1, $1\frac{1}{2}$ feet; No. 2, 3 feet.

No storage reservoirs.

Controlling factors of award: the award was a compromise. Our engineer, Mr. W. R. C. Corsons, figured damage at outside figure as No. 1 = $982; No. 2 = $488. Our opponents submitted no engineer's figures. Compromise was really based on these figures plus what their attorneys thought they could make it cost us to fight it out before a committee of the court.

In this state, water condemnation proceedings must be fought before a committee of three, appointed by a judge of the Superior Court, and all the expense must be borne by the Water Company.

$449 PER M.G.D. PER FOOT OF FALL.

37 District of Columbia, Washington, 1880.

The Great Falls Manufacturing Company of Virginia *v.* The United States.

DEVELOPED PRIVILEGE ON POTOMAC RIVER.

Authority: Francis F. Longley, Washington.

BY AWARD, $15 692 + expense of trial, $12 761.64 = $28 454.

Water supply of the District of Columbia.

No specific watershed diverted out of 11 043 square miles.

Amount of water diverted: not exceeded 71 000 000 gallons per day. Great Falls Mfg. Co. has formally recognized the right of the United States to take as much as 153 000 000 gallons per day.

Developed fall: diversion for water supply only. Entire fall still available for power development.

24 hour power.

Watershed: largely rough and mountainous, reached elevations of 4 000 feet. About one third of area wooded.

Water used only for water supply.

No storage reservoirs.

Controlling factors in award: (1) value of lands owned by claimants which were submerged by construction of dam for diversion of water supply; (2) value of the property rights of the claimants in

the water diverted from the Potomac River for the water supply of the District of Columbia.

SPECIAL DAMAGE.

38 Maine, ————, 1900, or thereabouts.

Names, Private.

UNDEVELOPED PRIVILEGE ON TRIBUTARY OF KENNEBEC RIVER.

Authority: Leonard Metcalf, Boston.

BY SALE, $13 000 approximately.

Total area of watershed above privilege: 200 square miles approximately.

Theoretical fall: 38 feet approximately in the aggregate; 775 HP., twenty-four hours, approximately $16 per HP.

$1.71 PER SQUARE MILE PER FOOT OF FALL.

39 Maine, ————, 1901, or thereabouts.

Names, Private.

UNDEVELOPED PRIVILEGE ON TRIBUTARY TO KENNEBEC RIVER.

Authority: Leonard Metcalf, Boston, Mass.

BY SALE, $24 000 approximately.

Total area of watershed above privilege: approximately 200 square miles.

Total fall: approximately 48 feet; 980 HP. approximately, $23.80 per 24 hour HP.

$2.50 PER SQUARE MILE PER FOOT OF FALL.

40 Maine, Waterville, 1903.

Maine Water Company *et al. v.* Kennebec Water District.

DEVELOPED PRIVILEGE.

Authority: Leonard Metcalf, Boston.

BY AWARD, $16 780.

Total area of watershed above privilege: 204 square miles.

Developed fall: 13 feet out of 13 feet $\backsimeq$ 265 HP. approximately $\backsimeq$ \$63.40 $\pm$ per HP.

24 hour power available.

Temporary wooden buildings; timber dam in good condition.

Watershed: undulating, timber, and agricultural; soil, clayey.

Water is used for other purposes than for power.

Award included allowances other than for water or water power.

$6.32 PER SQUARE MILE PER FOOT OF FALL, INCLUDING SMALL ALLOWANCES FOR BUILDINGS, ETC.

41 Massachusetts, ————, 1899.

DEVELOPED WATER PRIVILEGE ON CHARLES RIVER.

Authority: Charles W. Sherman, Boston.

BY AWARD, $9 900 (exclusive of interest).

Diversion: 2 000 000 gallons daily.

Fall: at 5 mill privileges aggregating 26.7 feet.

Power utilized: as 10 hour power.

$185.40 PER MILLION GALLONS DAILY PER FOOT OF FALL.

42 Massachusetts, Andover, 1892.

Essex Company *v.* Andover.

DEVELOPED PRIVILEGE.

Authority: Richard A. Hale, Lawrence, Mass.

BY AGREEMENT, $1 200.

Drainage area: 2.7 square miles.

Fall: 30 feet.

Haggett's Pond taken for water supply. The town uses only a small portion of the total yield and there is some wasted into the Merrimac River. This was taken into consideration somewhat in connection with the amount fixed.

$14.80 PER SQUARE MILE PER FOOT OF FALL.

43 Massachusetts, Auburn, Worcester County, 1895.

Wm. J. Hogg *et al.* (Stoneville Worsted Company privilege) *v.* City of Worcester (Kettle Brook Cases No. 12).

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $12 786 (exclusive of interest).

Watershed taken: 3.856 square miles out of 15.2175 square miles.

Horse-power taken (F. A. McClure, authority): Petitioners' claim, 38.84; defendant's claim, 20.56.

Fall: 23.75 feet.

Character of development: worsted yarns for carpets.

Character of watershed: typical New England.

Coal: $4.15 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

One 138 HP. wheel installed.

Total steam and electric power development: 200 HP.

Total power required: 200 HP.

Area of pond: 40 acres.

Working depth of pond: 40 inches.

$139.50 PER SQUARE MILE PER FOOT OF FALL.

44 Massachusetts, Avon (as of August 12, 1889, with interest from said date. Award 1896 [?]).

Marcus M. Porter *v.* Town of Avon.

SPRING IN FARM OF PETITIONER — PORTER'S SPRING.

Authority: William Wheeler, Boston, Mass.

BY AWARD: (Jury Superior Court), $4 750.

Water taken: average for dry year about 90 000 gallons per day.

$52 750 PER MILLION GALLONS PER DAY.

45 Massachusetts, Ayer, Shirley, and Harvard. Taking 1898. Award 1904.

Nashoba Manufacturing Company *v.* Commonwealth of Massachusetts.

DEVELOPED PRIVILEGE ON NASHUA RIVER.

Authority: Leonard Metcalf, Boston.

BY AWARD, $20 000, or $27 300 including interest.

Watershed diverted: 118.3 out of 302 square miles; from 118.3 square miles, except 12 to 24 000 000 gallons of water to be let down weekly; diversion, 78 HP., 24 hours ±.

Developed fall: 8 feet out of 8 feet.

10 hour power.

Wooden A frame dam, and brick and wooden mill; had been out of service more or less. Used by Nashoba Manufacturing Company and Nashoba Chemical Company. Had two wheels and steam boiler plant. Buildings and 13 acres of land.

Watershed: rolling country; agricultural and partly wooded.

Coal: $4.50 per long ton.

Steam used to limited extent for manufacturing and other purposes.

Water used to limited extent for other purposes than power.

Wheels installed: 2 Houston turbines, 65 HP. each.

Total steam and electric power development: 130 HP. approximately.

Total power required to run mill: uncertain and comparatively small amount.

Very little supplementary steam necessary; none for power.

Dam and plant rebuilt soon after award was made.

Approximate area of mill pond: 9 000 000 square feet (8 miles long).

Approximate depth to which pond can be drawn: practically less than 1 foot.

Storage reservoirs upon watershed: Metropolitan Water Board and some others. Perhaps as much as 200 000 000 cubic feet on entire watershed.

Control of watershed fair; action not united.

Controlling factor in award: water diversion.

No allowances other than for water or water power.

Consensus of opinion or average opinion is perhaps represented by the following figures: 400 HP. installation warranted; development sixth to eighth month; total watershed, 302 square miles, of which approximately 40 per cent. diverted.

$21.20 PER SQUARE MILE PER FOOT OF FALL.

46 Massachusetts, Billerica, 1878.

C. P. Talbot *et al.* and J. R. Faulkner *et al.* *v.* City of Boston.

DEVELOPED PRIVILEGE ON SUDBURY RIVER (Old Middlesex Canal Dam).

Authority: William Jackson and C. W. Sherman, Boston.

BY AWARD	(1)	**$76 000**	**BY SETTLEMENT**	(1)	**$57 375**
	(2)	**20 000**		(2)	**15 000**
Total,		**$96 000**	**Total,**		**$72 375**

Total amount including interest, etc., (1) $59 224.81.

Total amount including interest, etc., (2) 15 641.68.

Watershed diverted: 75.2 square miles out of 352 square miles; all but 1.5 m.g.d. of water.

Fall: 11 feet.

Award: $116.90 PER SQUARE MILE PER FOOT OF FALL.

Settlement: $87.50 PER SQUARE MILE PER FOOT OF FALL.

47 Massachusetts, Blackstone, Worcester County, 1895.

Lawrence Felting Company *v.* City of Worcester. (Kettle Brook Cases No. 33.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $6 300 (exclusive of interest).

Watershed above privilege: 3.856 square miles out of 253.0526 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 24.14; defendant's claim, 5.87.

Fall: 15 feet.

Character of development: felt linings for rubber goods.

Coal: $3.75 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

Five wheels, 886 HP.

Total steam and electric power development: 140 HP.

Power required: 800 HP.

Area of pond: 25 to 50 acres.

$108.80 PER SQUARE MILE PER FOOT OF FALL.

48 Massachusetts, Blackstone, Worcester County, 1895.

Earl P. Mason Land Company (Waterford, Evans & Seagraves privilege) *v.* City of Worcester. (Kettle Brook Cases No. 35.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $3 990 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 358.7658 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 17.15; defendant's claim, 4.20.

Fall: 10 feet.

Character of development: plant closed down.

Power required: 480 HP.

Area of pond: 50 acres.

$103.40 PER SQUARE MILE PER FOOT OF FALL.

49 Massachusetts, Blackstone, Worcester County, 1895.

Blackstone Manufacturing Company *v.* City of Worcester. (Kettle Brook Cases No. 34.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $12 285 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 256.0511 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 51.69; defendant's claim, 12.64.

Fall: 32.047 feet.

Area of pond: 68 acres.

Working depth of pond: 3 feet.

$99.40 PER SQUARE MILE PER FOOT OF FALL.

50 Massachusetts, Braintree, Norfolk County, 1893.

Quincy Water Company *v.* Quincy.

DEVELOPED WATER PRIVILEGE.

Authority: William Jackson, Boston, Mass.

BY AWARD, $599 304.19 (including interest and allowances).

Watershed above privilege: 990 acres.

Watershed taken: 990 acres.

Watershed: hilly.

Storage reservoirs upon watershed: 180 000 000 gallons.

Award included mains, reservoir, and franchise.

This case was one involving no mill rights.

SPECIAL.

51 Massachusetts, Canton, 1900.

Lexington Print Works *v.* Town of Canton.

DEVELOPED WATER-POWER PRIVILEGE ON BEAVER BROOK.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $1 000.

Watershed taken: about 2.60 square miles out of 2.68 square miles.

Amount of water taken: by collecting wells, estimated daily yield about 500 000 gallons.

Theoretical fall: 20.5 feet.

Fall used: 20.5 feet.

10 hour power.

Character of development: water power, silk print works.

Character of watershed: tillage, mowing and woodland.

Steam is used for manufacturing or other purposes.

Water is used for dyeing and printing also.

Approximate area of mill pond: 65 000 square feet.

Approximate depth to which mill pond can be drawn: 1.50 feet.

No storage reservoirs upon the watershed.

$18.80 PER SQUARE MILE PER FOOT OF FALL.

52 Massachusetts, Clinton, Worcester County, 1897.

Lancaster Mills, Sawyer's Mills *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGE, WACHUSETT RESERVOIR.

Authority: Charles T. Main, Boston.

BY AGREEMENT, $535 000 (Water and Water Rights, Lancaster, $289 000; Sawyer's, $62 000).

Watershed diverted: Sawyer's, 113.4 square miles out of 113.4; Lancaster, 118.23 square miles out of 118.23. All water taken except 12 to 24 million gallons per week, which was used for other purposes than power.

Fall developed: Sawyer's, 15 feet out of 15.50 feet; Lancaster, 28 feet out of 28 feet.

58 hours per week power.

Stone dam. Product, Lancaster: ginghams, cheviots, dress goods. Sawyer's (in excellent condition), product: yarn.

Watershed: typical New England.

Coal: $4.46 per short ton.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than for power.

Wheels installed: Lancaster, three, 535 HP. at 75 per cent. efficiency; Sawyer's, two, 196 HP. at 75 per cent. efficiency.

Total steam power development: Lancaster, 750 HP.; Sawyer's, 280 HP.

Total power required to run mill: Lancaster, 976 HP.; Sawyer's, 280 HP.

Supplementary steam is necessary, Lancaster, 755 HP.

Very little improvement necessary, Lancaster; Sawyer's might be developed up to about 340 HP.

Approximate area of mill pond: 96 acres, Lancaster; 71.6 acres, Sawyer's.

Approximate depth to which pond can be drawn: customary to draw 1 foot, Lancaster; Sawyer's maximum, 2 feet.

168 000 000 cubic feet storage reservoirs on watershed.

Storage controlled so as to be drawn out in times of low flow.

Controlling factors in award: both parties desire to settle amicably. Award based on extra cost of running mill after diversion.

Award included allowances for new steam plant; also land, mill buildings, tenements, and water power development at Sawyer's mill.

$87.30 LANCASTER, $35.20 SAWYER'S, PER SQUARE MILE PER FOOT OF FALL.

53 Massachusetts, Easthampton, Hampshire County, 1902.

Town of Easthampton *v.* City of Holyoke.

DEVELOPED PRIVILEGE (located on southwest branch of the Manhan River, which empties into the Connecticut).

Authority: J. L. Tighe, Holyoke.

BY AWARD, $22 000.

Watershed diverted: 13 square miles out of 60.5 square miles.

Fall developed: 16 feet out of 16 feet.

11 hour power.

Easthampton Water Works Pumping Station.

Watershed: mountainous, well wooded.

Auxiliary steam plant used only for pumping.

No water used for other purposes.

One wheel installed, 67 HP.; provision made for another.

To improve privilege: new dam must be built and another wheel installed.

Approximate area of mill pond: 1 acre ±.

Approximate depth to which mill pond can be drawn: 4 feet.

No storage reservoirs of any account upon watershed.

Controlling factors in award: claim that in time the pumping plant would have to be run twenty-four hours per day. Likewise, that the second wheel would soon be installed in order to run an electric plant for lighting town.

No allowances other than for the water or water power.

To the above award might be added about \$5 000 for legal and expert fees.

\$105.70 PER SQUARE MILE PER FOOT OF FALL.

54 Massachusetts, Framingham, 1878.

Saxonville Mills *v.* City of Boston.

DEVELOPED PRIVILEGE ON SUDBURY RIVER.

Authority: William Jackson and C. W. Sherman, Boston.

BY AWARD, \$175 000. SETTLEMENT, \$131 250 + Interest.

Total amount, including interest, etc., \$134 611.98.

Watershed diverted: 75.2 square miles out of perhaps 100 square miles. All except 1.5 m.g.d. of water.

Fall: 26 feet.

Award: \$89.60 PER SQUARE MILE PER FOOT OF FALL.

Settlement: \$67.20 PER SQUARE MILE PER FOOT OF FALL.

55 Massachusetts, Gardner (as of July 1, 1902).

Gardner Water Company *v.* Town of Gardner.

WATER SUPPLY PRIVILEGE IN CRYSTAL LAKE.

Authority: William Wheeler, Boston, Mass.

BY AWARD, \$90 000.

Character of privilege: Water of natural lake or pond taken or acquired under statute for water supply purposes by Gardner Water Company.

Watershed taken: 607.5 acres.

Amount of water taken: estimated 850 000 g.p.d.

Character of watershed: improved land (with some residences) and woodland.

Valued separately incident to the determination of the price to be paid by the town for the property rights and privileges of the Gardner Water Company.

\$106 000 PER MILLION GALLONS PER DAY.

56 Massachusetts, Gloucester (as of September 24, 1895), 1898.

City of Gloucester *v.* Gloucester Water Supply Company.

DEVELOPED WATER SUPPLY, DIKES MEADOW AND WALLACE BROOK.

Authority: William Wheeler, Boston, Mass.

BY AWARD: For water and water rights, exclusive of physical structures and lands,	\$175 000
Lands and physical structures, additional,	45 000
For water and water rights, lands, and physical structures, but not including interest,	\$220 000

Character of privilege: water of brook acquired or taken under statute and impounded for water supply purposes. Reservoired and improved.

Watershed taken: 585.5 acres.

Water taken: estimated daily average supply, 890 000 gallons per day.

Character of watershed: meadow and woodland.

Controlling factors in award: Valued separately incident to the determination of the fair value of all the corporate property, rights, and privileges of the Gloucester Water Supply Company purchased by the city of Gloucester.

$197 000 PER MILLION GALLONS PER DAY.

57 Massachusetts, Gloucester (as of September 24, 1895), 1898.
City of Gloucester *v.* Gloucester Water Supply Company.
UNDEVELOPED WATER SUPPLY, LILY POND AND MEADOW.
Authority: William Wheeler, Boston.

BY AWARD, $20 000 for water and water rights.

Character of privilege: Brook acquired and for a time used for water supply purposes without development, practically unreservoired and unimproved, but with right to use, and used to some extent for water supply purposes.

Watershed taken: 491 acres.

Theoretical fall: estimated 780 000 g.p.d.

Character of watershed: meadow and woodland.

Controlling factors in award: valued separately incident to the determination of the fair value of the corporate property rights and privileges of the Gloucester Water Supply Company purchased by the city of Gloucester.

$25 600 PER MILLION GALLONS PER DAY.

58 Massachusetts, Grafton, Worcester County, 1895.
Fisher Manufacturing Company (Fisherville privilege) *v.* City of Worcester. (Kettle Brook Cases No. 27.)
DEVELOPED PRIVILEGE.
Authority: Charles T. Main, Boston.

BY AWARD, $4 410 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 127.4373 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 17.16; defendant's claim, 6.30.

Fall: 11.02 feet.

Character of development: fancy cottons.

Coal: $3.60 per 2 000 pounds.

Steam is used for other purposes.
Three wheels installed, 380 HP.
Total steam and electric power development: 750 HP.
Power required: 1 150 HP.
Area of pond: 130 acres.
Working depth of pond: 2 feet.

$103.70 PER SQUARE MILE PER FOOT OF FALL.

59 Massachusetts, Grafton, Worcester County, 1895.

Wm. H. Whitman (Farnumsville Cotton Mill privilege) *v.* City of Worcester. (Kettle Brook Cases No. 28.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $3 570 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 128.3622 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 13.45; defendant's claim, 3.74.
Fall: 8 feet.
Character of development: cotton prints and drilling.
Coal: $3.60 per 2 000 pounds.
Steam is used for other purposes.
Two 160 HP. wheels installed.
Total steam and electric power development: 170 HP.
Power required: 300 HP. approximately.
Area of pond: 10 acres.
Working depth of pond: $1\frac{1}{4}$ feet.

$115.60 PER SQUARE MILE PER FOOT OF FALL.

60 Massachusetts, Grafton, Worcester County, 1895.

Saunders Cotton Mill, Saunders Grist Mill *v.* City of Worcester. (Kettle Brook Cases Nos. 25 and 26.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $7 980 (exclusive of interest).

Watershed above privilege: cotton mill, 85.5005 square miles; grist mill, 88.7790 square miles.
Watershed diverted: 3.856 square miles.
Horse-power taken (F. A. McClure, authority): Petitioners' claim, 20.60 and 11.11; defendant's claim, 3.64.
Fall: cotton mill, 12.77 feet; grist mill, 8.04 feet.
Character of development: cotton mill, sheetings, etc.; grist mill.

Coal: $3.75 per 2 000 pounds.

Wheels installed: cotton mill, four, 561 HP.; grist mill, one, 45 HP.

Total steam and electric power development: cotton mill, 250 HP.; grist mill, none.

Power required: cotton mill, 320 HP.

Area of pond: cotton mill, 10 acres; grist mill, 5 acres, perhaps.

Cotton mill can be drawn very little.

$99.40 PER SQUARE MILE PER FOOT OF FALL.

61 Massachusetts, Groton, Middlesex County, 1898.

Tileston & Hollingsworth Company *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AGREEMENT, $34 500.

Watershed diverted: 118.23 square miles out of 428.48 square miles. About 175 c.f.s. of water.

Developed fall: 7.5 feet out of 8 feet.

24 hour power.

Paper mill: water wheels supplemented by steam.

Watershed: typical New England.

Coal: $3.59 per short ton.

Steam not used for manufacturing or other purposes to any great extent.

Water not used for other purposes than for power to any great extent.

Five wheels installed, 342 HP. Usually run at about 180 HP.

Total steam power development: 200 HP. H-C engine; could develop 300 HP.

Total power required to run mill: average, 200 HP.

Supplementary steam rated at 200 HP.

Approximate area of mill pond: 140 acres.

Approximate depth to which pond can be drawn: 1 foot.

585 000 000 cubic feet storage reservoirs on watershed.

Storage controlled so as to be drawn during times of low flow.

Controlling factors in award: both parties desire to settle amicably. Award based on extra cost of running the mill after the diversion.

No allowances other than for the water or water power.

This was a paper mill with one paper machine and other machinery which goes to make a complete mill, driven when possible by water power, but at times of low or high water supplementary steam was used.

$37 PER SQUARE MILE PER FOOT OF FALL.

62 Massachusetts, Haverhill, 1896.

F. H. West *v.* City of Haverhill.

DEVELOPED MILL PRIVILEGE ON EAST MEADOW RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $3 000.

Watershed taken: 7.75 square miles out of 7.75 square miles.

Amount of water taken: estimated 7 500 000 g.p.d.

Theoretical fall: 9 feet.

Fall used: 9 feet.

10 hour power.

Approximate area of mill pond: 66 670 square feet.

Approximate depth to which mill pond can be drawn: 1.2 feet.

$43.00 PER SQUARE MILE PER FOOT OF FALL.

63 Massachusetts, Haverhill, 1899.

Kendall Shattuck *v.* City of Haverhill.

DEVELOPED MILL PRIVILEGE ON EAST MEADOW RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $3 000 (about).

Watershed taken: 7.5 square miles out of 7.5 square miles.

Amount of water taken: estimated 7 500 000 g.p.d.

Theoretical fall: 8 feet.

Fall used: 8 feet.

10 hour power.

Character of development: grain and cider mill.

Approximate depth to which mill pond can be drawn: 1 foot.

One wheel installed: 42-inch.

Approximate area of mill pond: 5 acres.

$50.00 PER SQUARE MILE PER FOOT OF FALL.

64 Massachusetts, Holyoke, 1900.

Lyons Bros. *v.* City of Holyoke.

DEVELOPED PRIVILEGE ON SOUTHWEST BRANCH OF MANHAN RIVER, WHICH EMPTIES INTO CONNECTICUT.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $9 682.72, including interest.

Watershed diverted: 13 square miles out of 27.53 square miles; all the water from watershed diverted.

Developed fall: 13½ feet out of 13½ feet.

Intermittent power.

Saw and grist mill.

Watershed: mountainous.

No steam used for manufacturing or other purposes.

No water used for any other purposes than for power.

Two wheels installed; 40 inch Leffel, and 24 inch McCormick; total, 117 HP.

Approximate area of mill pond: 2 acres ±.

Approximate depth to which mill pond can be drawn: to any economic depth.

No storage reservoirs upon watershed.

Controlling factors in the award: diversion of water alone.

No allowances other than for water or water power.

Typical country sawmill and grist mill; as may be noticed, wheel capacity is over-developed. The reason was that the mills were independently run and both mills were never run at the same time.

$55.20 PER SQUARE MILE PER FOOT OF FALL, including interest.

$49.30 PER SQUARE MILE PER FOOT OF FALL, excluding interest (estimated).

65 Massachusetts, Hopkinton, Middlesex County, August 2, 1894.

(*a*) Dwight Printing Company, (*b*) Wood Bros. & Newhall *v.* City of Boston.

DEVELOPED WATER PRIVILEGE UPON SUDBURY RIVER BELOW WHITEHALL POND.

Authority: William Jackson, Boston, Mass.

BY AWARD, (*a*) $193 000; (*b*) $93 500. Total, $286 500 (includes real estate; not separable).

Area of watershed taken and diverted: 4.892 square miles.

Fall used: Wood Bros., 8.25 feet; Dwight Manufacturing Company, 13.5 feet.

Character of watershed: moderately hilly; typical New England watershed.

Storage reservoirs upon watershed: 1 256 900 000 gallons.

The award included real estate.

$2 694 PER SQUARE MILE PER FOOT OF FALL, including large amounts for land, etc. (special case).

66 Massachusetts, Hudson, Middlesex County, 1897.

F. Brigham & Co. *v.* City of Marlboro.

DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $3 440 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 64.26 square miles.

Amount of water taken:
Actual, 3 247 000 gallons per twenty-four hours.
Available, 1 238 000 ,, ,, ,, ,,
Theoretical fall: 9 feet.
Fall used: 9 feet.
10 hour power.
Character of development: wool scouring, box making, and laundry. Partly in disuse since 1881 and 1894 owing to destruction of mills by fire.
Character of watershed: generally farming, pasturage, and woodland.
Three wheels installed, 123 HP.
Approximate area of mill pond: 2 166 000 square feet.
Approximate depth to which mill pond can be drawn: 1 foot.
Character of control: dam.

$113.00 PER SQUARE MILE PER FOOT OF FALL.

67 Massachusetts, Kingston, Plymouth County, 1907.
Town of Kingston *v.* City of Brockton.

DEVELOPED PRIVILEGE ON JONES RIVER.

Authority: Arthur T. Safford, Lowell, Mass.

BY AWARD, $17 000.

Watershed diverted: 4.4 square miles, including Silver Lake, out of 19.8 square miles; 4 000 000 gallons per day of water.
Developed fall: 8 feet out of 8 feet.
Power is used practically all the time.
Water power pumping plant for supplying town with water. Structures of wood, but in good condition.
Watershed: low (elevation less than 100 feet above sea level) meadows, swamps, and wooded, sandy.
Coal: $6 per short ton. Electric current, 3 cents per k.w.h.
No steam used for manufacturing or other purposes.
No water used for any other purposes than for power.
Wheels installed: one for pumping station; one for tack factory across the stream using surplus water; 25 HP.
Total power required to run pumps: 13 HP.
Supplementary current not used until after 1906, then 20 HP. motor; current from Plymouth, Mass.
Improvements: new wheel for pump; keeping water up in mill pond; cleaning out tailrace, estimated cost, $1 000.
Approximate area of mill pond: small, 5 acres.
Approximate depth to which pond can be drawn: 2 feet.
Storage reservoir: one at Silver Lake. Area at full lake, 646 acres; 540 000 000 gallons in upper 2.5 feet.

Control of storage: no deeded right, but accustomed to use storage with others at the outlet and lower down on the stream, and the town has had privilege of opening gates and letting out water when shops at outlet were shut down.

Controlling factors in award: the value of the storage which, previous to 1906, had made it possible for the town to pump continuously by water (with one exception when the flume was repaired) from 1886 to 1906; during very dry times the amount pumped was limited from upward of 300 000 gallons per day to perhaps 100 000 gallons; surplus power leased to tack factory for $300 a year; also the cost and maintenance of the electric motor and pumps to make up for 12.9 HP. for three months.

No allowance in award for other than water and water power.

The pumping station of the town of Kingston, operated by water power previous to 1906 without any auxiliary power, was, I believe, the only one of its kind in New England. The operating expenses per million gallons, $7.37,* are lower than any figures which I have been able to find. The pump operated itself and left the superintendent free to attend to all the business of the water works. The figures of the award were based practically upon replacing the power taken away for three months in the year with electric current bought from the Plymouth Electric Light Company, and the actual figures of maintenance in the future will not be less than the figures on which the award was based.

$483 PER SQUARE MILE PER FOOT OF FALL.

68 Massachusetts, Lancaster and Clinton, Worcester County, 1897.

George W. White *v.* Metropolitan Water Board.

DEVELOPED PRIVILEGE ON SOUTH BRANCH OF NASHUA RIVER.

Authority: Charles T. Main, Boston.

BY AGREEMENT, $35 000.

Watershed diverted: 118.2 square miles out of 128.8 square miles; 243 c.f.s. average of water.

Developed fall: 7.5 feet net head acting on wheels out of 8 feet.

Intermittent power.

Cotton mill: water wheels very old; dam in good condition.

Watershed: typical New England.

Three wheels installed; 150 HP. at 75 per cent. efficiency; no steam.

Total power required to run mill: 125 HP.

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* Including salary of superintendent.

Approximate area of mill pond: 28.2 acres.
Approximate depth to which pond can be drawn: 1 foot.
168 000 000 cubic feet of storage reservoirs upon watershed.
Storage controlled so as to be drawn in times of low flow.
Controlling factors in award: both parties desired to settle amicably.
Whole property taken, but value of buildings and machinery very small.

$37 PER SQUARE MILE PER FOOT OF FALL.

69 Massachusetts, Lawrence, Essex County, 1896.
Essex Company *v.* Metropolitan Water Board (in Boston).
FULLY DEVELOPED PRIVILEGE ON MERRIMAC RIVER.
Authority: Charles T. Main, Boston.
BY AGREEMENT, $87 000 (exclusive of interest).

Watershed diverted upon the Nashua River, 118.23 square miles out of 4 599 square miles; 2.9 per cent. of water.
Developed fall: 30 feet out of 32.5 feet.
Largely 10 hour power, some 24 hour.
Very complete development belonging to Water Power Company furnishing water to various mills along the canals.
Watershed: typical New England.
Coal: $4.24 per short ton.
Steam is not produced by the Water Power Company, but by the water takers.
Water takers do use water for other purposes than power.
Water furnished to a large number of wheels belonging to different corporations.
Approximate working depth of mill pond: 3 feet.
Large number of storage reservoirs upon watershed tributary to Merrimac River.
Controlling factor in the award, desire to settle amicably.
No allowance in award other than for water or water power.

$22.62 PER SQUARE MILE PER FOOT OF FALL.

70 Massachusetts, Lawrence, Essex County, 1878.
Essex Company *v.* City of Boston.
DEVELOPED PRIVILEGE ON SUDBURY RIVER.
Authority: William Jackson and C. W. Sherman, Boston; Richard A. Hale, Lawrence.
BY AWARD, $35 000. SETTLEMENT, $26 250 + Interest. Total amount, including interest, etc., $27 164.59.

Total watershed: 4 553 square miles.
Watershed diverted: 75.2 square miles; all the water except 1.5 m.g.d.

Fall: 32 feet.

Settlement: $10.90 PER SQUARE MILE PER FOOT OF FALL.

Award: $14.50 PER SQUARE MILE PER FOOT OF FALL.

71 Massachusetts, Leicester, Worcester County.

Anjeanette K. Smith *v.* City of Worcester. (Kettle Brook Cases No. 6.)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $26 609 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 6.1379 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 38.29; defendant's claim, 28.51.

Fall: 23.28 feet.

Character of development: flannels and dress goods; dyeing for other mills.

Character of watershed: typical New England.

Coal: $3.80 per 2 000 pounds.

Steam is used for other purposes.

Water is used for washing and dyeing.

One 80 HP. wheel installed.

Total steam and electric power development: 100 HP.

Total power required: 150 HP.

Area of pond: 8 to 10 acres.

$296.70 PER SQUARE MILE PER FOOT OF FALL.

72 Massachusetts, Leicester, Worcester County, 1895.

Leicester Water Power Company *v.* City of Worcester. (Kettle Brook.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $5 250 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 4.8207 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 14.75.

Fall: 10.82 feet.

Character of development: storage reservoir between Kents, Lakeside Manufacturing Company, and Darling's Shoddy Mill, owned by an association of mill owners below.

Character of watershed: typical New England.

Area of pond: 70.46 acres.

Award practically for storage reservoir only. No power. Watershed actually diverted is 3.6158 square miles, to which is added half the

watershed of Peter Brook, since the tribunal included this area in making its awards.

SPECIAL.

73 Massachusetts, Leicester, Worcester County, Mass.

A. W. Darling, Lessee, *v.* City of Worcester. (Kettle Brook Cases No. 1)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $1 760 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 4.8207 square miles.

Horse-power taken (F. A. McClure, authority): Defendant's claim, 20.86; petitioner's claim, 29.82.

Fall: 17.25 feet.

Character of development: small affair; shoddy.

Character of watershed: typical New England.

Steam is used for heating.

One wheel installed; 57 HP.

Total steam development: 55 HP.

Power required: 40 HP.

Area of pond: storage reservoir a few hundred feet above, 96 acres, owned by mill owners below.

Working depth of pond: little.

SEE KETTLE BROOK CASE NO. 2 — NEXT MILL.

74 Massachusetts, Leicester, Worcester County, 1895.

A. W. Darling *et al.*, Lessees, *v.* City of Worcester. (Kettle Brook Cases No. 1.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD $862 (exclusive of interest).

Watershed taken: 3.856.

Fall: 17.84.

(AWARD INCLUDED WITH CASE NO. 2.)

75 Massachusetts, Leicester, Worcester County.

E. D. Thayer, Owner, *v.* City of Worcester. (Kettle Brook Cases No. 2.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $30 669 (exclusive of interest).

Watershed taken: 3.856 square miles out of 5.0169 square miles.

Horse-power taken (F. A. McClure, authority): Petitioners' claim, 33.89; defendant's claim, 23.47.
Fall: 22.35 feet.
Character of development: woolens.
Coal: $4 per 2 000 pounds.
Live steam, heating, and drying.
Water is used for wool washing.
One wheel installed, 45 HP.
Power required to run mill: 110 HP.
Area of mill pond: 3 or 4 acres.
Award included: (*a*) Darling Shoddy Mill or (*b*) Bottomly Mill privilege; (*c*) undeveloped privilege.
(*a* and *b* are covered under Nos. 73 and 74.)

$211.20 PER SQUARE MILE PER FOOT OF FALL, including preceding case.

76 Massachusetts, Leicester, Worcester County, 1895.
E. D. Thayer *et al.* (Paxton Reservoir) *v.* City of Worcester.
NO POWER.
Authority: Charles T. Main, Boston.
BY AWARD, $36 750 (exclusive of interest).
Watershed diverted: 1.805 square miles out of 1.805 square miles.
Fall: variable.
Character of watershed: typical New England.
Award covers reservoir, dam, and land only; no power.

SPECIAL.

77 Massachusetts, Leicester, Worcester County.
Eli Collier (formerly Dixon privilege) *v.* City of Worcester. (Kettle Brook Cases No. 4.)
DEVELOPED WATER PRIVILEGE.
Authority: Charles T. Main, Boston.
BY AWARD, $10 159 (exclusive of interest).
Watershed diverted: 3.856 square miles out of 5.1711 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 17.71; defendant's claim, 12.70.
Fall: 10.87 feet.
Character of development: 1 set mill; satinet.
Character of watershed: typical New England.
Cost of coal: $4 per 2 000 pounds.
Steam is used for other purposes.
Water is used for washing and fulling.
One 29 HP. wheel installed.

Total steam and electric development: 50 HP.
Power required: 40 HP.
Area of pond: 1¼ acres approximately.
Working depth: 18 inches perhaps.

$242.80 PER SQUARE MILE PER FOOT OF FALL.

78 Massachusetts, Leicester, Worcester County, 1895.
E. D. Thayer *et al.* *v.* Worcester.
ABANDONED PRIVILEGE.
Authority: Charles T. Main, Boston.
Watershed diverted: 2.528 out of 2.528 square miles.
Fall: 11 feet.
Saw mill privilege.
Includes dam and land.

SPECIAL.

79 Massachusetts, Leicester, Worcester County, 1895.
Town of Leicester *v.* City of Worcester.
DEVELOPED PRIVILEGE.
Authority: Charles T. Main, Boston.
BY AWARD, $1 890 (exclusive of interest).
Watershed diverted: 2.608 out of 2.608 square miles.
Fall: 18 feet.
Character of watershed: typical New England.
Award included land.

SPECIAL.

80 Massachusetts, Leicester, Worcester County, Mass.
Channing Smith, Lessee, *v.* City of Worcester. (Kettle Brook Cases No. 7.)
DEVELOPED WATER PRIVILEGE.
Authority: Charles T. Main, Boston.
BY AWARD, $2 212 (exclusive of interest).
Watershed diverted: 3.856 square miles.
Fall: 5.86 feet.

$98 PER SQUARE MILE PER FOOT OF FALL.

81 Massachusetts, Leicester, Worcester County, 1895.
E. D. Thayer *et al.*, Arnold Reservoir, *v.* City of Worcester.
ABANDONED PRIVILEGE.
Authority: Charles T. Main.
BY AWARD, $3 950 (exclusive of interest).
Watershed above privilege: 1.151 square miles.

Watershed taken: 1.151 square miles.
Fall: 8 feet.
Character of development: abandoned for many years. Old dam and rollway standing, nothing more.
Character of watershed: typical New England.
Area of pond: 5 or 6 acres.
Award covers reservoir, dam, and land only. No power.

SPECIAL.

82 Massachusetts, Leicester, Worcester County.
Waity M. Olney *et al.* *v.* City of Worcester. (Kettle Brook Cases No. 5.)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $36 550 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 6.1379 square miles.
Horse-power taken (F. A. McClure, authority): Petitioners' claim, 46.62. Defendant's claim, 31.00.
Fall: 25.89 feet.
Character of development: six set mill. Blankets, etc. Has settling pond above.
Character of watershed: typical New England.
Coal: $3.90 per 2 000 pounds.
Steam is used for heating and washing.
Water is used for washing.
One wheel installed, 106 HP.
Total steam and electric power development: 90 HP.
Total power required: 150 HP.
Area of pond: 8 to 10 acres.
Working depth: perhaps 2 feet.
Award included: *a.* George W. Olney privilege.
b. Watson privilege.
c. Sawmill privilege.

$366.10 PER SQUARE MILE PER FOOT OF FALL.

83 Massachusetts, Leicester, Worcester County.
Newton Darling, Chapel Mills privileges, *v.* City of Worcester. (Kettle Brook Cases No. 3.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $14 671 (exclusive of interest).

Watershed taken: 3.856 square miles out of 5.0169 square miles.

Horse-power taken (F. A. McClure, authority): Petitioners' claim, 25.34. Defendant's claim, 17.30.
Fall: 14.77 feet.
Character of development: canal from tailwater of power above, about 873 feet long, 12 to 15 feet wide. Woolens.
Character of watershed: typical New England.
Cost of coal: $4.00.
Live steam for heating.
One 36 HP. wheel.
Total steam and electric power development: 50 HP.
Power required to run mill: 60 to 70 HP.

$257.50 PER SQUARE MILE PER FOOT OF FALL.

84 Massachusetts, Leicester, Worcester County, 1895.
Geo. Mann *et al.* *v.* City of Worcester.

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $44 000 (exclusive of interest).

Watershed diverted: 3.0968 square miles out of 3.0968 square miles.
Fall: 49.75 feet.
Character of development: mill abandoned, dam cut by city of Worcester about May, 1896. Woolens and shoddy.
Character of watershed: typical New England.
Coal: $4.70 per 2 000 pounds.
Steam is used for heating mill.
Water is used for washing.
Two wheels installed, 87 HP.
Total steam and electric power development: about 40 HP.
Power required: probably 60 HP.
Area of pond: 24½ acres.
Working depth of pond: 2 feet.
Award included: *a.* Mann & Marshall mill and other premises.
b. Mann Bros. undeveloped privilege between reservoir and mill pond.
c. Mann Bros. mill pond and privilege.
d. Mann Bros. undeveloped privilege below mill.
Land, mill, and tenement buildings, canals, etc., included.

SPECIAL.

85 Massachusetts, Lowell, 1878.
(1) M. P. Wilder *et al.* *v.* City of Boston.
(2) L. W. Faulkner *v.* City of Boston.
(3) C. Brown Snyder *v.* City of Boston.

(4) Belvidere Woolen Company *v.* City of Boston.
(5) Sam'l N. Wood *v.* City of Boston.
(6) Lowell Bleachery *v.* City of Boston.
(7) Wamesit Power Company *v.* City of Boston.
(8) American Bolt Company *v.* City of Boston.

DEVELOPED PRIVILEGE ON SUDBURY RIVER (WAMESIT DAM).

Authority: William Jackson and C. W. Sherman, Boston.

BY AWARD: (1) $16 500; (2) $15 000; (3) $24 000; (4) $40 000, including damages at another privilege; (5) $7 500; (6) $6 000.

BY SETTLEMENT: (1) $12 375; (2) $11 287.50; (3) $18 072; (4) $30 000 (including also damages at another privilege; assume half to each privilege); (5) $5 643.74; (6) $4 515; (7) $55 000; (8) $9 000.

(7 and 8 did not join in suit.)

Total, $145 892.50 — $15 000 (% other privileges) = $130 892.50.

Watershed diverted: 75.2 square miles out of 370 ±; all the water except 1.5 m.g.d.

Fall: 24.8 feet.

Settlement: $70.90 per Square Mile per Foot of Fall (approximately) for 8 Mills.

86 Massachusetts, Lowell, 1878.

Nancy L. Richmond *v.* City of Boston.

DEVELOPED PRIVILEGE ON SUDBURY RIVER.

Authority: William Jackson and C. W. Sherman, Boston.

BY AWARD, $23 000. SETTLEMENT, $17 307.50; $17 973.10, including interest, etc.

Watershed diverted: 75.2 square miles out of 375 ± square miles. All the water except 1.5 m.g.d.

Fall: 8 feet.

Award: $38.30 per Square Mile per Foot of Fall.

Settlement: $28.80 per Square Mile per Foot of Fall.

87 Massachusetts, Lowell, 1878.

Belvidere Woolen Company and Middlesex Company *v.* City of Boston.

DEVELOPED PRIVILEGE ON SUDBURY RIVER.

Authority: William Jackson and C. W. Sherman, Boston.

BY AWARD: (1) $40 000. Settlement, $30 000, including another privilege on Wamesit dam.

(2) Did not join in suit. Settlement, **$22 544.95**, including interest. Probably about **$20 000** without interest.

Assuming one half of (1) to relate to other privilege. total settlement = **$15 000** + **$20 000** = **$35 000.**

Total Payment, including interest:

(1) **$31 150.22.**

(2) **$22 544.95.**

Watershed diverted: 75.2 square miles out of 380 ± square miles, All water taken except 1.5 m.g.d.

Fall: 11.3 feet.

Settlement: $41.10 PER SQUARE MILE PER FOOT OF FALL.

88 Massachusetts, Lowell, Essex County, 1896.

Locks and Canals Company *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGE ON MERRIMAC RIVER.

Authority: Charles T. Main, Boston.

BY AGREEMENT, $116 000.

Watershed diverted: 118.23 square miles out of 4 085 square miles; 2.9 per cent. of water.

Developed fall: 34 feet out of 39 feet.

Largely 10 hour power, some 24 hour.

Very complete development belonging to the water power company furnishing water to the various mills along the canals.

Watershed: typical New England.

Coal: $4.24 per short ton.

No steam produced by the water power company; steam power produced by the water takers.

Water takers do use water for other purposes than for power; water power company does not.

Water furnished to a large number of wheels belonging to the different corporations.

Approximate area of mill pond: 1 125 acres.

Approximate depth to which mill pond can be drawn: 3 feet.

Storage reservoirs on watershed tributary to Merrimac River.

Controlling factor in the award: desire to settle amicably.

No allowances in award for other than water or water power.

$25.15 PER SQUARE MILE PER FOOT OF FALL.

89 Massachusetts, Maynard, Middlesex County, 1897.

Assabet Manufacturing Company *v.* City of Marlboro.

DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $8 385 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 113.12 square miles.
Amount of water taken:
Actual, 3 247 000 gallons per twenty-four hours.
Available, 1 238 000 ,, ,, ,, ,,
Theoretical fall: 22.2 feet.
Fall used: 22.2 feet.
10 hour power.
Character of development: woolen goods.
Character of watershed: generally farming, pasture, and woodland.
Four wheels installed, 650 HP.
Approximate area of mill pond: 10 154 000 square feet.
Approximate depth to which mill pond can be drawn: 1 foot.
Character of control of storage: dam.

$111.00 PER SQUARE MILE PER FOOT OF FALL.

90 Massachusetts, Maynard, Middlesex County, 1897.
Assabet Manufacturing Company *v.* City of Marlboro.
DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.
Authority: William Wheeler, Boston, Mass.

BY AWARD $4 225 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 113.12 square miles.
Amount of water taken:
Actual, 3 247 000 gallons per twenty-four hours.
Available, 1 238 000 ,, ,, ,, ,,
Theoretical fall: 12 feet.
Fall used: 12 feet.
10 hour power.
Character of development: paper mill, burned in 18—.
Character of watershed: generally farming, pasture, and woodland.
Four wheels installed, 200 HP.
Approximate area of mill pond: 10 154 000 square feet.
Approximate depth to which mill pond can be drawn: 1 foot.
Character of control of storage: dam.

$103.50 PER SQUARE MILE PER FOOT OF FALL.

91 Massachusetts, Maynard, Middlesex County, 1897.
American Powder Mills *v.* City of Marlboro.
DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.
Authority: William Wheeler, Boston, Mass.

BY AWARD, $4 080 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 115.61 square miles.

Amount of water taken:
Actual, 3 247 000 gallons per twenty-four hours.
Available, 1 238 000 ,, ,, ,, ,,
Theoretical fall: 10.8 feet.
Fall used: 10.8 feet.
10 hour power.
Character of development: manufacture of powder.
Character of watershed: generally farming, pasture, and woodland.
Two wheels installed, 193 HP.
Approximate area of mill pond: 1 486 000 square feet.
Approximate depth to which mill pond can be drawn: 0.6 feet.
Character of control of storage: dam.

$111.00 PER SQUARE MILE PER FOOT OF FALL.

92 Massachusetts, Middleboro, 1909.
Town of Middleboro *v.* City of Taunton.
DEVELOPED WATER PRIVILEGE, NEMASKET RIVER.
Authority: George A. King, Taunton, Mass., and Leonard Metcalf, Boston.
AWARD, $7 500 ± exclusive of interest.
Interest from July 2, 1895, costs of court, and interest on decree to time of payment make total paid $13 913.63.
Area of watershed: 59 square miles.
Watershed diverted: 48.1 square miles + a portion from 10.9 square miles additional area.
Water diverted: actual, less than 2 m.g.d.; assumed, 5 m.g.d. approximately.
Fall: 10 feet.
Fall used: 10 feet.
24 hour power used.
Electric lighting plant.
Watershed: flat, sandy, partly wooded.
Coal: $4.50 per short ton.
Steam is used for power.
Water is not used for any other purpose than power.
Two 75 HP. wheels installed; 36-inch wheels.
Power development: 1 steam engine, 150 HP. 2 gas engines, 125 HP. each (?). Water power, 125 HP. to 150 HP.
Power required to run mill: 150 HP. approximately. Peak load, 300 HP. ±.
Supplementary steam and producer gas is necessary.
To improve privilege, power must be developed on other side of river. Now under other ownership.
Area of mill pond: 16 000 feet long by 100 feet wide.
12 000 000 gallons per foot depth.

Working depth of pond: efficient limit, say, 1 foot.

Storage reservoirs: 2.5 feet depth upon Assawompsett and Pocksha

Ponds,	2 160 million gallons.
Great and Little Quittacus,	1 190 ,, ,,
Long Pond,	1 350 ,, ,,
Total,	4 700 million gallons.

Character of control of storage: perfect.

The defendant claimed no damage, as the regimen of the stream was so improved by the provision for control of the lake outlet as to make the actual summer flow greater than before the development, in spite of the amount of diversion. The plaintiff claimed that while it might be to the interest of both parties to so control the discharge of water from the lake as to materially increase the summer flow, the actual control of the flash or weir boards had been taken out of their hands. Under the original act granting authority to divert water from these ponds for the water supply of Taunton, the right was granted to build a dam and raise the water level in the ponds 2.5 feet, or to such an amount as to provide one year's supply, and the city was required "to maintain . . . the natural flow . . . at all times."

$12.70 PER SQUARE MILE PER FOOT OF FALL.

93 Massachusetts, Nashua River Cases, 1896 or thereabouts.
SUMMARY OF METROPOLITAN WATER BOARD CASES.
Authority: Dexter Brackett, Boston.

AMOUNTS PAID BY AGREEMENT FOR DIVERSION OF WATER AND WATER RIGHTS TAKEN IN CONNECTION WITH THE METROPOLITAN WATER WORKS.

	Diversion of Water.	Value of* Water Rights (Approximate).	Mill Property.	Depreciation of Real Estate and Loss of Business.	Total.	For Water or Water Rights per Square Mile per Foot of Fall.
Essex Company, Lawrence, Mass.	$87 000	....	....	....	$87 000	$22.60
Locks and Canals, Lowell, Mass.	116 000	....	....	....	116 000	25.15
Nashua Manufacturing Company, Nashua, N. H.	183 750	....	....	....	183 750	33.60
Jackson Manufacturing Company, Nashua, N. H.	149 100	....	....	....	149 100	58.00
West Boylston Manufacturing Company, Oakdale, Mass.	....	$90 000	$435 000	....	525 000	35.15
Clarendon Mills, West Boylston, Mass.	....	53 000	187 000	....	240 000	29.10
Lancaster Mills, Clinton, Mass.	289 000	....	....	....	289 000	87.30
Sawyer's Mills, Clinton, Mass.	....	62 000	184 000	....	246 000	35.20
Holbrook Mills, West Boylston, Mass.	....	22 000	78 000	....	100 000	20.70
Cowee Mills, West Boylston, Mass.	....	22 000	37 500	$13 000	72 500	20.70
White's Grist Mill, Lancaster and Clinton, Mass.	35 000	....	....	....	35 000	37.00
Tileston & Hollingsworth Co., Groton, Mass.	34 500	....	....	....	34 500	37.00
*Nashua River Paper Company, Pepperell, Mass.	145 895	....	....	....	145 895	49.70
L. M. Harris Manufacturing Company, Oakdale Mass.	....	52 000	142 000	....	194 000	24.30

* Judgment,	$111 666.67
Interest,	34 186.82
Costs,	41.62
	$145 895.11

94 Massachusetts, Millbury, Worcester County, 1895.
Worcester and Suburban Street Railway Company *v.* City of Worcester. (Kettle Brook Cases No. 18.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 200 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 57.8271 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 17.73; defendant's claim, 3.94.
Fall: 11.20 feet.
Character of development: electric current.
Coal: $4 per 2 000 pounds.
Water is used for other purposes.
1 wheel installed.
Total steam and electric power development: 500 HP.
Power required to run mill: probably 500 HP.

$97.20 PER SQUARE MILE PER FOOT OF FALL.

95 Massachusetts, Millbury, Worcester County, 1895.
Anna L. Morse *et al.* *v.* City of Worcester. (Kettle Brook Cases No. 19.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $2 940 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 62.9134 square miles.
Horse-power taken (F. A. McClure, authority): Petitioners' claim, 13.22; defendant's claim, 2.84.
Fall: 8 feet.
Character of development: sash and blinds, inside finish.
Character of watershed: typical New England.
Coal: $3.80 per 2 000 pounds.
Two 116 HP. wheels installed.
Total steam and electric power development: 60 HP.
Power required: 90 to 100 HP.
Area of pond: 4 or 5 acres.
Working depth of pond: 18 inches.

$95.40 PER SQUARE MILE PER FOOT OF FALL.

96 Massachusetts, Millbury, Worcester County, 1895.
Wm. Harrington (Atlanta Mills privilege) *v.* City of Worcester. (Kettle Brook Cases No. 20.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 620 (exclusive of interest).

Watershed taken: 3.856 square miles out of 70.2969 square miles

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 19.38; defendant's claim, 2.88.

Fall: 12.2 feet.

Character of development: not known; mill has been closed for a long time.

One wheel installed: 48 inches.

Area of pond: 3 to 4 acres.

$98.30 PER SQUARE MILE PER FOOT OF FALL.

97 Massachusetts, Millbury, Worcester County, 1895.

J. H. Mason *et al.* (Millbury Cotton Mill privilege) *v.* City of Worcester. (Kettle Brook Cases No. 21.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 830 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 70.2969 square miles.

Horse-power taken (F. A. McClure, authority): Petitioners' claim, 20.91; defendant's claim, 4.51.

Fall: 13.1 feet.

Character of development: print goods.

Coal: $3.85 per 2 000 pounds.

Two 278 HP. wheels installed.

Total steam and electric power development: 220 HP.

Power required: 240 HP.

Area of pond: 1 acre.

Working depth of pond: little.

$95.70 PER SQUARE MILE PER FOOT OF FALL.

98 Massachusetts, Millbury, Worcester County, 1895.

Cordis Mills *v.* City of Worcester. (Kettle Brook Cases No. 22.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $5 460 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 70.4939 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 23.74; defendant's claim, 5.28.

Fall: 14.27 feet.

Character of development: cotton tickings.

Coal: $3.60 per 2 000 pounds.

Steam is used for other purposes.
One 225 HP. wheel installed.
Total steam and electric power development: 240 HP.
Power required: 275 HP.
Area of pond: 7 acres.
Working depth of pond: 16 inches to 24 inches.

$99.30 PER SQUARE MILE PER FOOT OF FALL.

99 Massachusetts, Millbury, Worcester County, 1895.
Charles T. Aldrich (Aldrich Mill privilege) *v.* City of Worcester. (Kettle Brook Cases No. 23.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $5 040 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 76.8691 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 23.02; defendant's claim, 2.88.
Fall: 16 feet.
Character of development: satinets.
Coal: $3.75 per 2 000 pounds.
Steam used for other purposes.
One 121 HP. wheel installed.
Total steam and electric power development: 180 HP.
Power required: 160 HP.
Area of pond: 5 acres.
Working depth of pond: 2 feet.

$81.80 PER SQUARE MILE PER FOOT OF FALL.

100 Massachusetts, New Bedford, 1899.
Town of Middleboro *v.* City of New Bedford.

DEVELOPED PRIVILEGE ON ASSAWOMPSETT POND, GREAT AND LITTLE QUITTACUS PONDS, LONG POND, ELDER'S POND, NEMASKET RIVER.

Authority: William F. Williams, New Bedford.

BY AGREEMENT, $4 800 (exclusive of interest); $6 800 (including interest for seven years).

Watershed diverted: 12.8 square miles out of 59 square miles; all of the water for the six dry months of the year.
Developed fall: 10 feet.
Water power used nights and steam or gas engine daytimes when water was low.
Character of development: generation of electric light and power.

Watershed: wooded land, grass land, general farming land, and some residential.

Steam is used for manufacturing or other purposes.

Water is not used for other purposes than for power.

Two turbine wheels installed of 75 HP. each.

Total steam and electric power development:

One 120 kilowatt machine.
One 35 ,, ,,
One 50-light arc machine.
One 30 ,, ,, ,,

The plant had one 150 HP. McIntosh steam engine and one 125 HP. gasoline engine.

Approximate area of mill pond: from the dam at the power station to the dam at Assawompsett Pond was about 36 acres.

Controlling factors in award: city had previously settled the claim of one other mill owner on the Nemasket River for the sum of \$4 500. The conditions were rather more favorable to Middleboro's claim; therefore the offer of counsel for the town to settle for \$4 800 and interest was accepted without relation to the value of the privilege on a horse-power basis.

No allowance for other than water or water power.

This case was settled by the city solicitor before the engineers for the city had completed their estimates and the collection of data for the defense. In determining the amount of the Star Mill damage (\$4 500) Messrs. Rice and Evans estimated the total horse-power equivalent of the water which the city might take to be 18 HP., which they gave a value of \$5 000.

The act under which the city took the waters of Great Quittacus Pond did not follow the usual phraseology of water acts. See Sect. 6, Acts 345, 1894. "Said city shall be liable to pay all damages that may be sustained . . . by any owner of water rights on or below the Nemasket River caused by the diminution of the natural flow of the waters from Great Quittacus Pond under the provisions of this act." . . . "No application for assessment of damages shall be made for the taking of any water, water right, or any injury thereto until the water is actually withdrawn by said city under the authority of this act."

One of the ablest lawyers in this state drew the act and I am sure it was his intention to make the city liable only for the actual diminution of the natural flow from Great Quittacus. The damage was not created by the paper taking. The damage depended upon the actual diminution in flow and could not be determined prior to such diminution.

It would have been an interesting case to try and I was sorry to see it settled.

\$37.50 per Square Mile per Foot of Fall.

101 Massachusetts, Northampton, 1901.

——————— *v.* City of Northampton.

DEVELOPED PRIVILEGE ON MILL RIVER.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $6 500 (including interest).

Watershed diverted: 7.2 square miles out of 13 square miles; all of the water from watershed of 7.2 square miles.

Developed fall: 30 feet out of 30 feet.

10 hour power when running.

Grist and saw mill.

Watershed: mountainous.

No steam used for manufacturing or other purposes.

No water used for any other purposes than for power.

One wheel installed: 80 HP.

No steam or electric power development.

Auxiliary power needed in dry periods, but none installed.

Approximate contents of mill pond: 670 000 cubic feet.

No storage reservoirs upon watershed except as above.

Storage controlled by gates.

Controlling factor in award: damage to grist mill.

No allowances other than for water or water power.

The above plant was a typical one of the country sawmill or grist mill. It was located about three miles from the railroad and this fact lessened the value of the privilege. There is a large undeveloped fall here, but this was hardly considered at all in settlement of damages.

$30.90 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$27.60 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

102 Massachusetts, Northampton, 1901.

——————— *v.* City of Northampton.

DEVELOPED PRIVILEGE ON WEST BROOK IN WEST WHATELY, MASS. (a tributary of Mill River, which empties into the Connecticut).

Authority: J. L. Tighe, Holyoke.

BY AWARD, $3 000 (including interest).

Watershed diverted: 7.2 square miles out of 13.1 square miles; all water from shed diverted.

Developed fall: 11.5 feet out of 18.5 feet.

10 hour power when running; mill run only intermittently.

Saw mill and general jobbing shop.

Watershed: mountainous.
No steam used for manufacturing or other purposes.
No water used for any other purposes than for power.
One wheel installed: 30 HP.
No steam and electric power development.
Total power required to run mill: all that the wheel would give at times.
Supplementary steam would be necessary for a uniform power.
Approximate area of mill pond: very small; has the use of the storage of 650 000 cubic feet of the ——— privilege.
Approximate depth to which mill pond can be drawn: any economical depth.
No storage reservoirs upon watershed except the ——— privilege.
Controlling factor in award: simply the damage done by diversion.
No allowances other than for the water or water power.

A typical country saw mill and grist mill. It was not used much for sawing or for making cider for many years, but confined entirely to running a job shop where the power needed was not more than from 10 to 20 HP.

$22.50 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$20.10 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

103 Massachusetts, Northampton, 1901.
——————— *v.* City of Northampton.

DEVELOPED PRIVILEGE ON WEST BROOK IN WEST WHATELY, MASS. (tributary of Mill River, which empties into the Connecticut).

Authority: J. L. Tighe, Holyoke.

BY AWARD, $5 000.

Watershed diverted: 7.2 square miles out of 13.2 square miles; all water from watershed diverted.
Developed fall: 22½ feet out of 22½ feet.
10 hour power when working.
Product: oatmeal, grain, and lumber.
Watershed: mountainous.
No steam used for manufacturing or other purposes.
No water used for any other purposes than for power.
One wheel installed: 60 HP.
Total power required to run mill: at times all of the 60 HP.
Supplementary steam or electricity would be necessary if it were necessary to have power uniform.

Approximate depth to which mill pond can be drawn: to any economical depth.

One storage reservoir upon watershed having 700 000 cubic feet capacity, which is the storage attached to the ——— privilege alone.

Controlling factor in award: damage alone.

No allowance for other than water or water power.

$30.90 PER SQUARE MILE PER FOOT OF FALL.

104 Massachusetts, Northampton, 1901.

———————— *v.* City of Northampton.

DEVELOPED PRIVILEGE ON MILL RIVER.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $17 000 (including interest).

Watershed diverted: 7.2 square miles out of 47 square miles; all of water of the portion of watershed diverted.

Developed fall: 14.5 feet out of 14.5 feet.

10 hour power.

Product: machine tools and gun stock.

Watershed: partly mountainous and partly flat along valley of lower portion of stream.

Steam is sometimes used as an auxiliary in low water.

No water used for any other purposes.

Three wheels installed: 75 HP.

Total steam and electric power development: a gasoline engine of 50 HP.

Total power required to run mill: 70 HP.

Supplementary steam used in dry periods to the amount of 50 HP.

To improve privilege: construct new dam and more wheel capacity.

Approximate area of mill pond: very small; confined to bed of the stream.

Approximate depth to which mill pond can be drawn: to any economic depth.

No storage reservoirs of any account upon watershed, except the mill pond itself and storage at the ——— privilege of 628 000 cubic feet.

Control of storage: controlled by the ——— privilege.

Controlling factor in award: damage by diversion alone.

No allowances other than for water or water power.

$162.70 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$145.20 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

105 Massachusetts, Northbridge, Worcester County, 1895.
Riverdale Woolen Mill *v.* City of Worcester. (Kettle Brook Cases No. 30.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 830 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 133.9949 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 18.93; defendant's claim, 3.47.
Fall: 13 feet.
Character of development: wool and shoddy mills.
Coal: $3.60 per 2 000 pounds.
Steam is used for heating purposes.
Water is used for other purposes.
Two 260 HP. wheels installed.
Total steam and electric power development: 325 HP.
Power required: about 250 HP.
Area of pond: 10 acres.

$96.30 PER SQUARE MILE PER FOOT OF FALL.

106 Massachusetts, Northbridge, Worcester County, 1895.
Paul Whitin Manufacturing Company (Rockdale privilege) *v.* City of Worcester. (Kettle Brook Cases No. 29.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $4 830 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 131.7250 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 18.31; defendant's claim, 4.75.
Fall: 12.37 feet.
Character of development: cotton goods.
Coal: $3.60 per 2 000 pounds.
Steam is used for other purposes.
Three wheels installed, 330 HP.
Total steam and electric power development: 746 HP.
Power required: 1 200 HP.
Area of pond: 98 acres.
Working depth of pond: can be drawn down but little.

$101.10 PER SQUARE MILE PER FOOT OF FALL.

107 Massachusetts, Oakdale, Worcester County, 1896.

'West Boylston Manufacturing Company *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGE ON SOUTH BRANCH OF NASHUA RIVER.

Authority: Charles T. Main, Boston.

BY AGREEMENT: Water Rights, $90 000 + Mill Property, $435 000.

Watershed diverted: 94.8 square miles out of 94.8 square miles; all of the water diverted.

Developed fall: 27 feet out of 27 feet.

10 hour power.

White cotton mill.

Watershed: typical New England.

Coal: $4.25 per short ton.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than for power.

Two wheels installed, 617 HP.

Total steam power development: 500 HP.

Total power required to run mill: 600 HP.

Nearly full amount of power required to run mill.

Approximate area of mill pond: 48 acres.

Approximate depth to which mill pond can be drawn: 3 feet.

Storage reservoirs upon watershed: capacity unknown.

Storage controlled so as to be drawn in times of low flow.

Controlling factor in award: both parties showed a disposition to settle amicably.

Award included allowances for mill buildings, machinery, tenements, and land. Tenements and land estimated at $100 000.

$35.15 PER SQUARE MILE PER FOOT OF FALL.

108 Massachusetts, Oakdale, Worcester County, 1896.

L. M. Harris Manufacturing Company *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGE ON QUINEPOXET RIVER.

Authority: Charles T. Main, Boston.

BY AGREEMENT, $194 000 = (Water Rights, $52 000 + Mill, $142 000).

Watershed all diverted: Spinning mill, 53.76 square miles.
Weaving ,, 54.23 ,, ,,

Developed fall: Spinning mill, 20 feet out of 22.85 feet.
Weaving ,, 14.5 ,, ,, ,, 16.85 ,,

10 hour power.

Two distinct dams, ponds, canals, raceways, and wheel plants.

Product: cotton goods.

Watershed: typical New England.

Coal: $4.46 per short ton.

Steam is not used to any great extent for manufacturing or other purposes.

Water is not used to any extent for any other purpose than for power.

Spinning mill has 1 pair 24-inch Hunt wheels, 149 HP.

Weaving mill has 1 pair 33-inch Hercules wheels, 93 HP.

Total steam power development: Spinning mill, 90 HP.
Weaving ,, 50 ,,

Total power required to run mill: Spinning mill, 160 HP.
Weaving ,, 50 ,,

Supplementary steam or electricity equal to whole power of wheels.

Approximate area of mill pond: Spinning mill, about 4 acres.
Weaving ,, ,, 3 ,,

Approximate depth to which mill pond can be drawn: 1 foot.

Storage reservoirs on watershed of unknown capacity.

Storage controlled so as to be drawn in times of low flow.

Controlling factor in award: desire to settle amicably.

Allowances other than for water or water power: land, mill buildings, machinery, and tenements.

$24.30 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING MACHINERY, LAND, AND BUILDINGS.

109 Massachusetts, Pepperell, Middlesex County, 1901.

Nashua River Paper Company *v.* Metropolitan Water Board.

DEVELOPED PRIVILEGE UPON NASHUA RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $111 666.67 ($145 895, including interest and costs).

Watershed diverted: 118.23 square miles out of, upper mill, 434.06 square miles; lower mill, 434.08 square miles; 192.68 c.f.s. of water.

Developed fall: Upper mill, 14 feet out of 14 feet.
Lower ,, 5 ,, ,, ,, 5 ,,

24 hour power.

Stone dam and fair development at upper mill; lower mill, very low head. Product, paper.

Watershed: typical New England.

Coal: $4.02 per short ton.

Steam is used for manufacturing and other purposes.

Water is used for other purposes than power.

Nine wheels installed: 1 54-inch Hercules, 1 60-inch Hunt, 1 45-inch Tyler, 3 36-inch Blake, 3 60-inch Hunt. Upper mill, 540 HP.; lower mill, 162 HP.

Total steam power development: upper mill, 670 HP.; lower, 370.

Total power required to run mill: upper mill, 715 HP. without lights; lower mill, 370 HP. without lights.

Supplementary steam necessary: upper mill, 350 HP.; lower mill, 160 HP.; connected with wheels.

To improve privilege: head could be increased at great expense, which did not seem warranted.

Approximate area of mill pond: 88.9 acres.

Approximate depth to which mill pond can be drawn: $1\frac{1}{2}$ feet.

585 000 000 cubic feet of storage reservoirs on watershed.

Storage controlled so as to be drawn out in times of low flow.

Controlling factor in award: case settled in court after extended trial.

Award probably included some allowance for rearrangements and addition to steam plant.

$49.70 PER SQUARE MILE PER FOOT OF FALL.

110 Massachusetts, Southampton, 1900.

W. J. Lyman *v.* City of Holyoke.

DEVELOPED PRIVILEGE ON SOUTHWEST BRANCH OF MANHAN RIVER, WHICH EMPTIES INTO CONNECTICUT.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $1 775.89 (including interest).

Watershed diverted: 13 square miles out of 34.72 square miles; all of the water.

Developed fall: 9 feet from November 1 to April 12; 5 feet, balance of year.

Intermittent power.

Saw mill.

Watershed: mountainous.

No water used for any other purposes.

Wheels: 1 48-inch Leffel; under 9-foot head, 39 HP.; under 5-foot head, 16 HP.

No supplementary steam or electricity is necessary.

One storage reservoir upon watershed of approximately 2 acres.

Character of control: mill pond for Lyons mill about one mile up stream.

Controlling factor in award: diversion of water alone.

No allowances for other than water or water power.

$15.16 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$13.53 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

111 Massachusetts, South Deerfield, 1906.

———————— *v*. Town of South Deerfield.

DEVELOPED PRIVILEGE ON MILL POND.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $2 300 + 6 per cent for about two years.

Watershed diverted: 3.65 square miles out of 39.2 square miles.

Developed fall: 14.5 feet out of 14.5 feet.

10 hour power.

Product: machine tools and gun stock.

Watershed: partly mountainous and partly flat.

No steam used for manufacturing or other purposes except as an auxiliary in low water.

No water used for any other purposes than for power.

Three wheels installed: 75 HP.

Total steam and electric power development: a gasoline engine of 50 HP., or electricity.

Supplementary steam used in dry periods when gasoline power is used to the amount of 50 HP.

To improve privilege: construct new dam and a greater wheel capacity.

Approximate area of mill pond: small and confined to that caused by dam backing up water in bed of stream.

Approximate depth to which mill pond can be drawn: to any economic depth.

No storage reservoirs of any account upon watershed except the ——— privilege in West Whately, Mass., this being 638 000 cubic feet.

Storage controlled by the ——— privilege.

Controlling factors in award: damage caused by diversion.

No allowances other than for water or water power.

It was shown that while theoretically the South Deerfield fire district diverted the flow of 3.65 square miles of shed, on account of the population of the town, the actual amount taken would not exceed a few thousand gallons per day. This had quite an effect upon the jury, and most of them being farmers, to whom $1 000 appeared very big, gave a rather small verdict. Besides, the town being so small and poor, the verdict must be affected more or less thereby.

$43.50 PER SQUARE MILE PER FOOT OF FALL.

112 Massachusetts, Springfield, 1892.

Otis Company, Collins Manufacturing Company, Ludlow Manufacturing Company, Chicopee Manufacturing Company, and Dwight Manufacturing Company *v.* Springfield Water Company.

DEVELOPED WATER PRIVILEGE ON JABISH BROOK.

Authority: Elbert E. Lochridge, Springfield, Mass.

BY AWARD, JULY 16, 1902, $70 000 (representing a damage of **$45 000 and 6 per cent.). This amount was paid to an attorney, Judge Everett C. Bumpus, of Boston. He secured the settlement for the mill owners and arranged for the division of the amount among them. The Ames Sword Company, American Bicycle Company (July 25, 1902), and Lamb Knitting Machine Company settled jointly for $3 000. This also represents a smaller sum and interest for ten years.**

Springfield Water Department, of Springfield, diverted the water, corporate names of owners being given above. The mills listed lie along the Chicopee River from Ludlow, Mass., a distance of about six miles, to the junction of the Chicopee River with the Connecticut River in Chicopee.

Total watershed: several hundred square miles.

Watershed diverted: Jabish Brook watershed, 10.6 square miles.

Falls:	Otis Company, (Plus a portion included under Ludlow M'f'g Co.'s fall).	6.0 feet.
	Collins Manufacturing Company,	13.5 ,,
	Ludlow Manufacturing Company,	43.0 ,,
	Chicopee Manufacturing Company,	28.0 ,,
	Dwight Manufacturing Company,	33.0 ,,
	Total,	123.5 feet

Character of development: manufacturing of jute, linen, cotton, and a great diversity of manufacturing uses in towns of Chicopee and Chicopee Falls.

No information given as to amount of power used for various products, inasmuch as this was a settlement and none of these figures were produced. The watershed area and number of feet of fall are definite enough, however, to secure figures on this basis.

Watershed diverted was largely swampy and no section of it has any steep slopes.

As far as is known, damages were purely for power, and as developments are very large, this division was small proportionately.

Supplementary steam and electricity at present time are used in all the mills.

Average (of 5 cases): $34.30 PER SQUARE MILE PER FOOT OF FALL.

113 Massachusetts, Springfield, 1878.

Dwight Manufacturing Company, Chicopee Manufacturing Company, Indian Orchard Mills, Ludlow Manufacturing Company, Collins Manufacturing Company *v.* Springfield Water Company. First diversion.

DEVELOPED WATER POWER ALONG THE CHICOPEE RIVER.

Authority: Elbert E. Lochridge, Springfield, Mass.

BY AGREEMENT:	**$5 655.89**	**Dwight M'f'g Company**	**(1)**
	4 440.19	**Chicopee M'f'g Company**	**(2)**
	1 924.48	**Indian Orchard Mills**	**(3)**
	962.24	**Ludlow M'f'g Company**	**(4)**
	1 897.20	**Collins M'f'g Company**	**(5)**
	120.00	**Referee charges**	
	$15 000.00		

Total watershed: several hundred square miles.

Watershed diverted: 8.1 square miles Broad, Axe Factory, Cherry Valley, and Higher brooks, all tributaries to Chicopee River in town of Ludlow. Settlement included all water which could flow from this area.

Fall taken and developed:	(1)	33 feet.
	(2)	28 ,,
	(3)	33 ,,
	(4)	43 ,,
	(5)	13.5 ,,
Total,		150.5 feet.

Character of development: manufacturing of jute, linen, cotton, and a great diversity of manufacturing uses in towns of Chicopee and Chicopee Falls.

No information given as to amount of power used for various products, inasmuch as this was a settlement and none of these figures were produced. The watershed area and number of feet of fall are definite enough, however, to secure figures on this basis.

Watershed diverted was largely swampy and no section of it has any steep slopes.

As far as is known, damages were purely for power, and as developments are very large, this diversion was small proportionately.

Supplementary steam and electricity at present time are used in all the mills.

$21.10 PER SQUARE MILE PER FOOT OF FALL, Dwight Manufacturing Company.

19.60 PER SQUARE MILE PER FOOT OF FALL, Chicopee Falls Manufacturing Company.

7.20 PER SQUARE MILE PER FOOT OF FALL, Indian Orchard Mills.

2.80 PER SQUARE MILE PER FOOT OF FALL, Ludlow Manufacturing Company.

17.30 PER SQUARE MILE PER FOOT OF FALL, Collins Manufacturing Company.

$12.30 PER SQUARE MILE PER FOOT OF FALL, *Average* (of 5 mills).

114 Massachusetts, Stow, Middlesex County, 1897.

C. W. and A. D. Gleason *v.* City of Marlboro.

DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $3 425 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 77.01 square miles.

Amount of water taken:

Actual, 3 247 000 gallons per twenty-four hours.

Available, 1 238 000 „ „ „ „

Theoretical fall: 11.5 feet.

Fall used: 11.5 feet.

10 hour power.

Character of development: woolen goods.

Character of watershed: generally farming, pasture, and woodland.

Two wheels installed, 125 HP.

Approximate area of mill pond: 1 282 000 square feet.

Approximate depth to which mill pond can be drawn: 1.5 feet.

Character of control of storage: dam.

$87.70 PER SQUARE MILE PER FOOT OF FALL.

115 Massachusetts, Sutton, 1895.

Sutton Manufacturing Company (Wilkinsonville privilege) *v.* City of Worcester. (Kettle Brook Cases No. 24.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $8 820 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 84.7156 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 37.71; defendant's claim, 5.61.
Fall: 22 feet.
Character of development: print mill.
Coal: $4.60 per 2 000 pounds.
Steam is used for other purposes.
Two 258 HP. wheels installed.
Total steam and electric power development: 100 HP.
Power required: 300 HP.
Area of pond: 6 acres.
Working depth of pond: 2 feet.

$104.00 PER SQUARE MILE PER FOOT OF FALL.

116 Massachusetts, Uxbridge, Worcester County, 1895.
Calumet Woolen Company, (*a*) Calumet Privilege, (*b*) Hecla Privilege, *v.* City of Worcester. (Kettle Brook Cases Nos. 31 and 32.)

DEVELOPED PRIVILEGES.

Authority: Charles T. Main, Boston.

BY AWARD, $8 400 (exclusive of interest).

Watershed above privilege: Calumet, 138.8710 square miles.
Hecla, 140.0900 ,, ,,
Watershed diverted: 3.856 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 35.87; defendant's claim, 9.25.
Fall: Calumet, 12.00 feet.
Hecla, 10.00 ,,
Character of development: Calumet, woolens.
Hecla, ,,
Coal: Calumet, $4.25 per 2 000 pounds.
Hecla, 3.70 ,, ,, ,,
Steam is used for manufacturing purposes.
Water is used for other purposes.
Wheels installed: Calumet, one 180 HP. wheel.
Hecla, three 159 ,, ,,
Total steam and electric power development:
Calumet, 130 HP.
Hecla, 130 ,,
Power required: Calumet, 160 HP.
Hecla, 240 ,,
Area of pond: Calumet, 111 acres.
Hecla, 45 ,,
Working depth of pond:
Calumet, 1 foot.
Hecla, 2 ,,

A Single Award for Two Privileges.
$99 per Square Mile per Foot of Fall.

117 Massachusetts, Waltham and Watertown, 1887 or later.
Boston Manufacturing Company *et al.* *v.* City of Cambridge.
DEVELOPED WATER PRIVILEGE ON CHARLES RIVER.
Authority: L. M. Hastings, Cambridge, Mass.*
BY AWARD, $15 000 (at 4 dams).
Area of watershed above privilege: Boston Manufacturing Company, 251.42 square miles less 66.64 account diversion through Mother Brook. Somewhat greater at Ætna Mills and Watertown dam.
Watershed diverted: 23 square miles. (Stony Brook.)
Water taken: average yield by agreement of engineers, 22.3 m.g.d.

Fall used:	Boston Manufacturing Company,	12.10 feet.
	" " " Bleachery,	4.00 "
	Ætna Mills,	4.80 "
	Watertown dam,	5.80 "
	Total fall at dams,	26.70 feet.

Area of mill pond at Boston Manufacturing Company: about 5 miles long, say, 10 750 000 square feet.
Working depth of mill pond: 2 feet.
$24.40 per Square Mile per Foot of Fall.

118 Massachusetts, Waltham (or Weston).
"Rhoades Mill" *v.* City of Cambridge.
DEVELOPED WATER PRIVILEGE ON BRANCH OF STONY BROOK.
Authority: L. M. Hastings, Cambridge, Mass.
BY AWARD, $1 700.61 (including small amount of land).
Watershed above privilege: 4.14 square miles.
Amount of watershed taken: 4.14 square miles.
Amount of water diverted: 4 HP. (estimated).
Fall used: 8 feet.
$51.35 per Square Mile per Foot of Fall.

119 Massachusetts, Waltham, 1889 and 1898.
Roberts Mill *v.* City of Cambridge.
DEVELOPED WATER PRIVILEGE ON STONY BROOK.
Authority: L. M. Hastings, Cambridge, Mass.

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* Journal of the New England Water Works Association, June, 1893, p. 189.

BY AWARD: **\$23 468.33 in 1889.**
1 877.09 in 1898.

Total, **\$25 345.42**

Watershed diverted: 23 square miles out of a total watershed but very little larger.

Fall: 16 feet.

Value of water for manufacturing purposes included in award. This award included the value of the water diverted, and in addition an allowance of 900 000 gallons per day, to be taken by the Roberts Mill from the reservoir built by the city. This award included the value of the power and the value of the water for manufacturing purposes, which was claimed to be considerable. Exactly what the power was valued at I am unable to learn. The amount of power available at the Roberts Mill was estimated by the city of Cambridge at 45.33 HP. and the fall was 16 feet.

\$69.29 PER SQUARE MILE PER FOOT OF FALL, INCLUDING SUBSTANTIAL VALUE OF WATER FOR MANUFACTURING PURPOSES AND ALLOWANCE OF 900 000 GALLONS OF WATER PER DAY.

120 Massachusetts, Waltham.

Nathaniel Sibley *v.* City of Cambridge.

DEVELOPED WATER PRIVILEGE ON STONY BROOK, PRACTICALLY ABANDONED.

Authority: L. M. Hastings, Cambridge, Mass.

BY AWARD, \$10 000.

Watershed above privilege: $21\frac{1}{2}$ square miles.

Watershed diverted: 21.5 square miles.

Water taken: 37.9 HP. at upper dam.
44.1 ,, ,, lower ,,

Fall used: upper dam, 10.14 feet.
Lower ,, 19.5 ,,

Area of mill pond: 14.9 acres.

Working depth of mill pond: 2 feet.

This plant had been practically abandoned for a number of years.

\$15.72 PER SQUARE MILE PER FOOT OF FALL (including value of water for manufacturing purposes).

121 Massachusetts, Wellesley, 1877.

Mill Owners *v.* Town of Wellesley.

DEVELOPED PRIVILEGE ON CHARLES RIVER.

Authority: Richard A. Hale, Lawrence, Mass.

AGREEMENT.

Diversion of 500 000 gallons per twenty-four hours from the Charles River. The town paid the mill owners at the rate of $46.07 per foot fall for 500 000 gallons per twenty-four hours, and if additional water was to be drawn, the same rates were to be applied.

$92.14 PER MILLION GALLONS PER DAY PER FOOT OF FALL.

122 Massachusetts, West Boylston, Worcester County, 1896.
Holbrook Mills *v.* Metropolitan Water Board.
DEVELOPED PRIVILEGE ON NASHUA RIVER.
Authority: Charles T. Main, Boston.

BY AGREEMENT. Water Rights, $22 000. Mill Property, $78 000.

Watershed diverted: 98.3 square miles out of 98.3 square miles; 198.5 c.f.s. of water.

Developed fall: 10.5 to 11 feet out of 11 feet.

10 hour power.

Log dam about 10 feet high, 110 feet long. Rest of development rather crude and inexpensive. Product, light sheetings, cheese cloth, butter cloth.

Watershed: typical New England.

Coal: $4.46 per short ton.

Wheels installed: 1 Rodney Hunt, 54-inch; 128 HP. on 11-foot head.

Total steam power development: 89 HP.

Total power required to run mill: 120 HP.

Supplementary steam necessary: average for nine months, 49 HP.

Privilege could be improved by raising dam 3 feet.

Approximate area of mill pond: 7.6 acres.

Approximate depth to which pond can be drawn: 2 feet.

Controlling factors in award: desire to settle amicably. Award based on extra cost of running mill after diversion.

Award included allowance for value of mill buildings and tenements, machinery, water power plant, and privilege.

$20.70 PER SQUARE MILE PER FOOT OF FALL.

123 Massachusetts, West Boylston, Worcester County, 1903.
Cowee's Grist Mill *v.* Metropolitan Water Board.
FULLY DEVELOPED PRIVILEGE ON NASHUA RIVER.
Authority: Charles T. Main, Boston.

BY AGREEMENT, $22 000 Water Rights + $50 500 Mill Property, etc.

Watershed diverted: 98.3 square miles out of 98.3 square miles; 197 c.f.s. average of water.

Developed fall: not over 11 feet out of 11 feet.

Intermittent power.

Product: grist mill.

Watershed: typical New England.

Wheels installed; 2 48-inch Leffel; 1 36-inch Upham, 125 HP.

Total power required to run mill: 125 HP.; no other power.

Approximate area of mill pond: 7.6 acres.

Approximate depth to which mill pond can be drawn: 2 feet.

Storage reservoirs upon watershed: unknown capacity.

Storage controlled so as to be drawn in times of low flow.

Controlling factors in award: both parties desired amicable settlement.

Award included allowances for land, mill buildings, and machinery

$20.70 PER SQUARE MILE PER FOOT OF FALL.

124 Massachusetts, West Boylston, Worcester County, 1896.
Clarendon Mills *v.* Metropolitan Water Board.

DEVELOPED PRIVILEGE ON NASHUA RIVER.

Authority: Charles T. Main, Boston, Mass.

BY AGREEMENT, $240 000 (= Water Rights, $53 000 + Mill Property, $187 000).

Watershed diverted: all out of 98.9 square miles.

Developed fall: 18.4 feet out of 18.4 feet.

10 hour power.

Dam of rough rubble work about 135 feet long and 8 feet high. Canal, excavated open channel, very low. Tailrace, excavated channel, rather long. Product: corset jeans, crochet quilts, and sateens.

Watershed: typical New England.

Coal: $4.46 per short ton.

Steam used for manufacturing or other purposes.

Water used for other purposes than for power.

Wheels installed: 1 30-inch Hunt; 1 pair 42-inch Humphrey. 178 HP. at 75 per cent. efficiency.

Total steam power development: 140 HP.

Total power required to run mill: 350 HP.

Supplementary steam used: 248 HP. average year.

Wise to develop privilege up to 350 HP.

Approximate area of mill pond: .5 acres.

Approximate depth to which mill pond can be drawn: about 1 foot.

About 168 000 000 cubic feet storage reservoirs upon watershed.

Storage controlled so that they can be drawn during seasons of low flow.

Controlling factor in award: disposition to settle amicably.

Award included allowances for mill buildings and machinery, and tenements. Tenements and land estimated at $34 000.

An old mill in poor condition.

$29.10 PER SQUARE MILE PER FOOT OF FALL.

125 Massachusetts, Westfield, 1900.

——————— v. Town of Westfield.

DEVELOPED PRIVILEGE ON LITTLE RIVER.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $3 100 (inclusive of interest).

Watershed diverted: 6.4 square miles out of 81 square miles; all the water of the watershed taken.

Developed fall: 8 feet out of 8 feet.

10 hour power.

Machine works lathes.

Watershed: mountainous.

No water used for other purposes except for washing.

One wheel installed, 50 HP.

Total power required: in 1900 one wheel running at full gate was able to furnish the power required.

Supplementary steam plant is installed as an auxiliary in the dry periods.

To improve privilege: install another wheel and enlarge canal.

Approximate area of mill pond: very small, of no account.

Approximate depth to which mill pond can be drawn: about 3 feet.

There were a few small storage reservoirs on watershed, but so small that they were not considered.

Controlling factor in award: nothing but the taking away of the power.

No allowances other than for water or water power.

$60.60 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$54.10 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

126 Massachusetts, Westfield, 1900.

——————— v. Town of Westfield.

UNDEVELOPED PRIVILEGE ON MUNN'S BROOK, TRIBUTARY TO LITTLE RIVER.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $500 (including interest).

Watershed diverted: 6.4 square miles out of 21 square miles; all the water in 6.4 square miles.

Developed fall: 10 feet out of 10 feet.

Power not used for years.

Cider mill, burned down.

Watershed: one half mountainous and the other half comparatively flat.

Wheel power when mill was in use: supposed to be 20 HP.

Approximate area of mill pond: the bed of stream only with storage caused by dam.

No storage reservoirs upon watershed.

Controlling factor in award: farm on which mill site was located more valuable with the mill site attached than without it.

$7.82 PER SQUARE MILE PER FOOT OF FALL, INCLUDING INTEREST.

$6.98 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING INTEREST (estimated).

127 Massachusetts, Westfield, 1900.

——————— *v.* Town of Westfield.

TWO FULLY DEVELOPED PRIVILEGES ON LITTLE RIVER.

Authority: J. L. Tighe, Holyoke.

BY AWARD, $19 200 (including interest).

Watershed diverted: 6.4 square miles out of 76 and 80 square miles; total watershed diverted.

Developed fall: 10 feet and 18 feet out of 10 feet and 18 feet.

24 hour power.

Paper mills.

Watershed: mountainous.

Steam used as an auxiliary plant and for heating and drying purposes.

Water used for washing, etc.

Two wheels installed, Privilege No. 1, 112 HP.; two or three installed at Privilege No. 2, 235 HP.

Total power required to run mill: all that could be developed.

Supplementary steam used in dry periods equal to the total wheel power or nearly so.

Approximate area of mill pond: small.

Approximate depth to which mill pond can be drawn: to any economical depth, say 3 feet.

A few small storage reservoirs on watershed.

Controlling factor of award: taking away of the power.

No allowances other than for water and water power, except for interest.

The damage was a lump sum for both privileges: $19 200, including interest.

$107.00 per Square Mile per Foot of Fall, including Interest.

$95.60 per Square Mile per Foot of Fall, excluding Interest (estimated).

128 Massachusetts, Westvale (Concord Junction), Middlesex County, 1897.

Damon Manufacturing Company *v.* City of Marlboro.

DEVELOPED MILL PRIVILEGE ON ASSABET RIVER.

Authority: William Wheeler, Boston, Mass.

BY AWARD, $3 715 (add interest at 6 per cent. from July 11, 1892).

Watershed taken: 3.39 square miles out of 116.84 square miles.

Amount of water taken:

Actual, 3 247 000 gallons per twenty-four hours.

Available, 1 238 000 ,, ,, ,, ,,

Theoretical fall: 8.8 feet.

Fall used: 8.8 feet.

10 hour power.

Character of development: woolen goods and saw mill.

Character of watershed: generally farming, pasture, and woodland.

Four wheels installed, 79 HP.

Approximate area of mill pond: 2 073 000 square feet.

Approximate depth to which mill pond can be drawn: 1.2 feet.

Character of control of storage: dam.

$124.00 per Square Mile per Foot of Fall.

129 Massachusetts, Worcester, 1895–96. Summary of **Kettle Brook Cases.**

Mill Owners on Kettle Brook and Blackstone River *v.* City of Worcester.

DEVELOPED PRIVILEGES.

Authority: Charles T. Main, Boston, Mass.; F. A. McClure, Worcester.

No.	Name.	Total Area. Square Miles.	Area Diverted.* Square Miles.	Gross Fall. Feet.	Award.	Award per Square Mile per Foot of Fall.
1.	Darling Shoddy Mill, Leicester, Mass.	4.82		17.25		
2.	Bottomly Mill, Leicester, Mass.	5.02	3.856	23.35		
				39.60	$32 291.00	$211.20
3.	Chapel Mill, Leicester, Mass.	5.02	3.856	14.77	14 671.00	257.50
4.	Collier Mill, Leicester, Mass.	5.17	3.856	10.87	10 159.00	242.80
5.	Olney Mill, Leicester, Mass.	6.14	3.856	25.89	36 550.00	366.10
6.	A. K. Smith, Leicester, Mass.	6.14	3.856	23.28	26 609.00	296.70
7.	C. Smith, Leicester, Mass.	?	–	5.86	2 212.00	98.00
8.	Thayer, Worcester, Mass.	6.57	3.856	39.44	41 370.00	272.00
9.	Darling, Worcester, Mass.	6.57	3.856	15.08	15 571.50	268.00
10.	Butler, Worcester, Mass.	6.57	3.856	17.77	17 920.00	261.80
11.	King, Worcester, Mass.	8.43	3.856	18.00	†12 618.00	182.00
12.	Stoneville, Auburn, Mass.	15.22	3.856	23.75	12 786.00	139.50
13.	A. Curtis, Worcester, Mass.	28.68	3.856	11.00	4 980.00	117.20
14.	Curtis M'f'g Co., Worcester, Mass.	29.75	3.856	14.00	6 275.00	116.10
15.	Hopeville, Worcester, Mass.	40.24	3.856	6.94	3 215.00	120.00
16.	Pakachoag, Worcester, Mass.	40.98	3.856	9.45	4 460.00	122.30
17.	Stevens, Worcester, Mass.	56.37	3.856	9.00	5 368.00	154.50
18.	Burling, Millbury, Mass.	57.82	3.856	11.20	4 200.00	97.20
19.	Morse, Millbury, Mass.	62.91	3.856	8.00	2 940.00	95.40
20.	Atlanta, Millbury, Mass.	70.30	3.856	12.20	4 620.00	98.30
					(Mill closed)	
21.	Millbury, cotton mills	70.30	3.856	13.10	4 830.00	95.70
22.	Cordis Mills, Millbury, Mass.	70.49	3.856	14.27	5 460.00	99.30
23.	Aldrich, Millbury, Mass.	76.86	3.856	16.00	5 040.00	81.80
24.	Sutton, Sutton, Mass.	84.71	3.856	22.00	8 820.00	103.80
25.	Saunders, Grafton, Mass.	85.50	3.856	12.77		
26.		88.78		8.54		
				20.81	7 980.00	99.40
27.	Fisher, Grafton, Mass.	127.44	3.856	11.02	4 410.00	103.70
28.	Farnumsville, Grafton, Mass.	128.36	3.856	8.00	3 570.00	115.60
29.	Rochdale, Northbridge, Mass.	133.99	3.856	12.37	4 830.00	101.10
30.	Riverdale, Northbridge, Mass.	133.99	3.856	13.00	4 830.00	96.30

No.	Name.	Total Area. Square Miles.	Area Diverted.* Square Miles.	Gross Fall. Feet.	Award.	Award per Square Mile per Foot of Fall.
31.	Calumet & Hecla, Uxbridge, Mass.	138.87	3.856	12.00		
32.		140.09	3.856	10.00		
				22.00	$8 400.00	$99.00
33.	Lawrence Felting Company, Blackstone, Mass.	253.05	3.856	15.00	6 300.00	108.80
34.	Blackstone, Blackstone, Mass.	256.05	3.856	32.05	12 285.00	99.40
35.	Waterford, Blackstone, Mass.	358.76	3.856	10.00	3 990.00	103.40
36.	Bartlett & Ballou, Woonsocket, R. I.	365.21	3.856	16.00	1 648.00	
				18.33		
37.	O'Reiley Grist Mill			18.33	268.50	
	Harris Woolen			18.33	268.50	
	Lyman Mill			18.33	446.00	
	Globe Mill			18.33	945.00	
	Woonsocket Electric Machine, etc.			16.66	3 717.00	
	Ray Cotton — Woonsocket, R. I.	365.21		13.00		103.95
	Lippitt			7.33	1 050.00	
	Lippltt			16.66		
	Leicester Knitting			7.00	210.00	
	Am. Worsted			16.67	840.00	
	Eagle Mills			14.66	1 092.00	
	Cliuton			14.66	1 680.00	
38.	Hamlet, Woonsocket, R. I.	367.40	3.856	9.33	3 150.00	87.70
39.	Mannville, Cumberland, R. I.	426.15	3.856	18.82	7 980.00	109.80
40.	Valley Falls (Albion)	429.40	3.856	13.20	4 515.00	88.80
41.	Lonsdale	433.03	3.856	10.00		
	Cumberland, R. I.	440.81	3.856	25.20	8 400.00	86.40
	Lincoln, R. I.	440.81	3.856	15.20		
42.	Valley Falls, Valley Falls, R. I.	442.52	3.856	14.61	5 040.00	89.40
43.	Central Falls, R. I., 3 mills	472.07	3.856	10.79	1 680.00	
					1 155.00	
					1 200.00	
					4 035.00	97.00
44.	Pawtucket, R. I., 5 mills			7.07	525.00	
				7.07	525.00	
		472.52	3.856	7.07	525.00	82.15
				8.00	336.00	
				7.07	367.00	
45.	Pawtucket, R. I., 3 mills			17.02	2 810.00	
		472.52	3.856	17.02	3 096.00	92.45
				10.93	105.00	
					Average,	$137.22

* Includes half of the watershed of Peter Brook, since it is understood that the commissioners included this in making their awards.

† This award not accepted and another trial was held and new award made, figures of which are not available.

130 Massachusetts, Worcester, 1895.

Albert W. Darling *v.* City of Worcester. (Kettle Brook Cases No. 9.)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $15 571.50 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 6.5723 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 24.28; defendant's claim, 13.35.

Fall: 15.08 feet.

Character of development: woolens, two set mills.

Steam is used for heating.

Water is used for other purposes.

One wheel installed, 30 HP.

Total steam and electric power development: 80 HP.

Power required: 75 HP.

Area of pond: 1 acre.

Working depth of pond: small.

$268.00 PER SQUARE MILE PER FOOT OF FALL.

131 Massachusetts, Worcester, 1895.

Curtis Manufacturing Company *v.* City of Worcester. (Kettle Brook Cases No. 14.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $6 275 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 29.7476 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 20.98; defendant's claim, 6.88.

Fall: 14 feet.

Character of development: shoddy mill.

Coal: $3.75 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

Two wheels installed: 120 HP.

Total steam and electric power development: 100 HP.

Total power required: 150 HP.

Area of pond: 50 acres.

Working depth of pond: 2 feet.

$116.10 PER SQUARE MILE PER FOOT OF FALL.

132 Massachusetts, Worcester, 1895.

E. D. Thayer, Jr., *v.* City of Worcester. (Kettle Brook Cases No. 8.)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $41 370 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 6.5723 square miles

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 64.47; defendant's claim, 40.67.

Fall: 39.44 feet.

Character of development: woolens and cotton warp cassimeres.

Coal: about $4.00 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

Two wheels installed, 118 HP.

Total steam and electric power development: 280 HP.

Power required: 275 HP.

Area of pond: 2 acres.

Working depth of pond: 2 feet.

Award included Ashworth & Jones privilege, E. D. Thayer, Jr., privilege.

$272.00 PER SQUARE MILE PER FOOT OF FALL.

133 Massachusetts, Worcester, 1895.

Albert Curtis *v.* City of Worcester. (Kettle Brook Cases No. 13.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 980 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 28.6828 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 16.65; defendant's claim, 9.02.

Fall: 11 feet.

Character of development: shoddy.

Coal: $3.75 per 2 000 pounds.

One wheel installed, 75 HP.

Area of mill pond: 161 acres.

Working depth of pond: 1 foot.

$117.20 PER SQUARE MILE PER FOOT OF FALL.

134 Massachusetts, Worcester, 1895.

Hopeville Manufacturing Company *v.* City of Worcester. (Kettle Brook Cases No. 15.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $3 215 (exclusive of interest).

Watershed taken: 3.856 square miles out of 40.2424 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 10.75; defendant's claim, 4.49.

Fall: 6.94 feet.

Character of development: woolens; 6 set mill.

Coal: $3.80 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

Two 62 HP. wheels installed.

Total power development: 250 HP.

Total steam and electric power development: 200 HP.

Area of pond: 7 acres.

Working depth of pond: very little.

$120.00 PER SQUARE MILE PER FOOT OF FALL.

135 Massachusetts, Worcester, 1895.

William J. Hogg (Pakachoag Mill privilege) *v.* City of Worcester. (Kettle Brook Cases No. 16.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $4 460 (exclusive of interest).

Watershed diverted: 3.856 out of 40.98 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 14.91; defendant's claim, 4.17.

Fall: 9.45 feet.

$122.30 PER SQUARE MILE PER FOOT OF FALL.

136 Massachusetts, Worcester, 1895.

George A. Stevens *v.* City of Worcester. (Kettle Brook Cases No. 17.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $5 368 (exclusive of interest).

Watershed diverted: 3.856 out of 56.3699 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 14.44; defendant's claim, 2.63.

Fall: 9 feet.

Character of development: grain mill.

Coal: $3.60 per 2 000 pounds.

Three 54 HP. wheels installed.

Power required: 75 HP.

Area of pond: 2 acres, including canal.

Working depth of pond: very little.

$154.50 PER SQUARE MILE PER FOOT OF FALL.

137 Massachusetts, Worcester, 1895.

Elizabeth A. Butler *v.* City of Worcester. (Kettle Brook Cases No. 10.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $17 920.25 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 6.5723 square miles.
Fall: 17.77 feet.
Horse-power taken (F. A. McClure, authority): Petitioner's claim 28.36; defendant's claim, 19.70.
Character of development: satinets; 2 set mill.
Coal: $3.80 per ton.
Steam is used for other purposes.
Water is used for other purposes.
One wheel installed, 60 HP.
Total steam and electric power development: 90 HP.
Power required: 75 HP.
Area of pond: 2 acres.
Working depth of pond: little.

$261.80 PER SQUARE MILE PER FOOT OF FALL.

138 Massachusetts, Worcester, 1895.

H. W. King, Trustee, *v.* City of Worcester. (Kettle Brook Cases No. 11.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $12 618 (exclusive of interest). (See remarks.)

Watershed diverted: 3.856 square miles out of 8.4358 square miles.
Fall: 18 feet.
Character of development: satinet.
Coal: $3.70 per ton.
Steam is used for other purposes.
Water is used for other purposes.
One wheel installed, 100 HP.
Total steam and electric power development: 80 HP.
Power required: 80 HP.
Area of pond: 25 acres.
Working depth of pond: 3 feet.
This award was not accepted, and a new trial was held, results of which are not available.

$182.00 PER SQUARE MILE PER FOOT OF FALL.

139 Maryland, Relay, Baltimore and Howard counties, October 2, 1902.

The Baltimore County Water and Electric Company purchased from the Viaduct Manufacturing Company of Baltimore City.

DEVELOPED PRIVILEGE ON YANTIC RIVER.

Authority: Kenneth Allen, New York City.

BY PURCHASE: Right to divert 3 000 000 gallons of water per day with additional diversion up to 150 000 000 gallons per day in 5 000 000 gallon lots per day upon payment of $1 000 per million of rights.

Total watershed above privilege: about 280 square miles.

Amount diverted: 3 000 000 gallons daily out of total estimated average flow of 150 000 000 gallons daily.

Developed fall: about 10 feet. Effective on wheels: about 7 feet.

Power used during usual working hours.

Character of development: manufacturing telephones and other electrical appliances.

Watershed: hilly, partly wooded, partly cultivated.

Coal: $3 per short ton.

Steam used only as auxiliary.

Water used only for power.

Four wheels installed, three of 27 HP. and one of 35 HP. One of the four running under part gate only, so that total available HP. equals 90.

Total steam power development: 50 HP.

Total power required to run mill: 90 HP.

112 HP. probably available.

Mill pond about 400 feet by 1 000 feet, with available depth of about 2 feet.

There are a number of dams with pondage upon the watershed of unknown capacity.

Character of control of storage: that usual in cases of water power plants for mill operation.

Award did not include any allowances other than for the water power.

The controlling features in sale were as follows: In a report made October 7, 1901, to the Viaduct Manufacturing Company by Hill, Quick & Allen, consulting engineers, it was estimated that with the existing development of 90 HP. auxiliary steam would be required sixty-seven days in the year. The water which the Baltimore County Water Company proposed to divert at that time did not exceed 2 000 000 gallons per day, and their engineers estimated that the maximum future diversion would not exceed 10 000 000

gallons per day, "but he stated that, to avoid detracting from the market value of the property, should it ever be deemed advisable to sell out, the company would not want any restrictions placed on the amount of water withdrawn from the stream." There being no guarantee as to the amount of diversion and as it might, indeed, be thought desirable to enlarge the plant later, so as to supply certain additional districts, the consulting engineers suggested "as the fairest and best basis of a settlement for the proposed curtailment of these privileges *the discounted value of the entire anticipated water power at some remote future date.*" This date was placed at the year 1951 or in fifty years.

The cost per horse-power of steam power was taken at $50 more per annum than water power, from which the potential value of the 112 HP. available was estimated at $5 600 per annum, and this amount was, therefore, decided to be the annual loss that would be sustained by the Viaduct Manufacturing Company.

The matter was finally adjusted upon the terms given in the answer to Question No. 1.

$100.00 per Million Gallons per Foot of Fall.

140 New Hampshire, ————————, 1907 to 1909.

Names private.

UNDEVELOPED PRIVILEGE.

Authority: Richard A. Hale.

BY SALE, $30 000 approximately, with provision for further payment under certain conditions in case of subsequent development of privilege.

Area of watershed: upwards of 3 000 square miles.

Available fall: less than 20 feet.

$4.70 per Square Mile per Foot of Fall.

141 New Hampshire, Ashland, July 23, 1888.

The Winnepissiogee Lake Cotton and Woolen Manufacturing Company to Messrs. Cheney, Scribner, and Stowell, of Ashland, N. H.

DEVELOPED WATER PRIVILEGES: ONE AT OUTLET OF LITTLE SQUAM LAKE, ONE IN ASHLAND VILLAGE.

Authority: W. E. Buck, Worcester, Mass.

SALE, $10 000, including 2 mills and various parcels of land.

Total watershed above privilege: $56\frac{3}{4}$ square miles.

Developed fall: at outlet, 15 feet; at Ashland Village, 14 feet.

Power used 24 hours per day.

Character of development: saw mill at outlet of lake; grist mill at Ashland Village.

Character of watershed: hilly and well wooded.

Area of mill pond: $11\frac{3}{4}$ square miles.

Working depth of mill pond: 3.5 feet.

Storage reservoirs upon watershed: Great and Little Squam Lakes.

Nearly complete control of storage by company.

The power at the outlet varies as the lakes are drawn down to supply the river. The Lake Company were under agreement to supply 75 c.f.p.s. on 24 hour schedule to the mill owners below whenever that amount would flow, and the supply seldom fell below that amount.

The power at Ashland Village is a very reliable power and was in use at time of sale for a grist mill and to run a small repair shop. The mills of course were included in the sale and various lots of land along the outlet of Little Squam Lake.

$6.08 PER SQUARE MILE PER FOOT OF FALL (including buildings and land).

142 New Hampshire, Bristol, July 29, 1884.

The Winnepissiogee Lake Cotton and Woolen Manufacturing Company to Josiah Minot, of Concord, N. H., and David Mason, of Bristol, N. H.

DEVELOPED WATER PRIVILEGES AT OUTLET OF NEWFOUND LAKE AND ON NEWFOUND RIVER.

Authority: W. E. Buck, Worcester, Mass.

SALE, $15 000 (exclusive of interest).

Watershed above privilege: 91 square miles.

Developed fall: at lake, about 9 feet, but less when lake is drawn down to supply river; at village, one power of entire river, 30-foot fall; one of about one-half river on 14-foot fall.

24 hour power.

Character of development: saw mill at outlet of lake; large power was in use for pulp mill at village; small power in use for repair shop.

Character of watershed: hilly and well wooded.

Area of Newfound Lake: $7\frac{3}{4}$ square miles.

Working depth of lake: 3 to 4 feet.

Control of storage good, but not sufficient storage to fully control water. Lake never fails to fill in spring, and large quantities of water run to waste at this season of year.

The power at outlet of lake is not of much value as the head is drawn down every season to supply the river. In most seasons the lake

will maintain a constant flow of about 90 c.f.s. for 24 hours per working day. The lower power at Bristol Village has the entire flow of the Newfound River on an available fall of 30 feet. This power well situated for a ground wood-pulp mill or an electric power station, but not for general mill use, as there is very little yard room. Above this, the small power, taking about half the flow of the river on 14-foot fall, is not of much value.

$3.58 PER SQUARE MILE PER FOOT OF FALL.

143 New Hampshire, Manchester, 1907.

Devonshire Mills *v.* City of Manchester.

DEVELOPED PRIVILEGES ON LAKE MASSABESIC.

Authority: George A. Kimball, Boston.

BY AWARD, $50 000 (exclusive of interest).

Watershed diverted: 45 square miles out of total area 66 square miles. The right to divert all the water above the outlet of Lake Massabesic, a watershed of 45 square miles.

Theoretical fall: 46 feet. Developed fall: 12 feet and 28 feet = 40 feet.

10 hour power.

Fourteen set mills used for production of woolen cloth.

Watershed: hilly.

Coal: $5.50 per long ton.

Steam used for wool scouring, dyeing, and heating mills.

Water used for wool scouring: about 350 000 gallons per day.

Water furnished to two wheels: 27-inch McCormick, 196 HP.; 48-inch Leffel.

Two horizontal boilers, 150 HP.; 1 horizontal, small; 1 steam engine, 225 HP.

To improve privilege: combine the two falls and utilize the whole fall of 46 feet.

Approximate area of mill pond: 53 acres.

Approximate depth to which mill pond can be drawn: 5.33 feet.

Storage reservoirs on watershed: 2 350 acres.

Control of storage: doubtful.

Allowances included use of water for wool scouring.

$24.20 PER SQUARE MILE PER FOOT OF FALL.

144 New Hampshire, Nashua, 1901.

Vale Mills *v.* Groton, Mass., Water Company.

DEVELOPED PRIVILEGE ON SALMON BROOK.

Authority: Arthur T. Safford, Lowell, Mass.

BY AWARD, $2 500, including small amount for interest and collateral items.

Watershed diverted: 1.1 square miles, including Baddacook Pond of about 100 acres, out of 29 square miles; 100 000 gallons per day of water; later, 200 000 gallons.

Developed fall: average, 14.79 feet for spinning mill out of 14 feet; average, 10.57 feet for weaving mill out of 11 feet.

12 hour power.

Two adjoining water powers; dams with masonry abutments across Salmon Brook in fair condition. Pondage and storage rights well defined; at time of award cotton mills shut down and since sold.

Watershed: wooded and cultivated land; swamps mostly between elevations 200 and 300; large shallow ponds and reservoirs.

Coal: must have been about $5 per short ton.

Steam was used for heating mills.

Water was used for sanitary purposes.

One wheel at each mill. Lower mill, 100 HP.; upper, 50 HP.

Total steam and electric power not known exactly, but must have been about 250 HP.

Total power required to run mill not known (shut down for good at time of investigation).

Supplementary steam or electricity was necessary at lower mill; amount not known.

To improve privilege: new wheels, perhaps $2 000.

Approximate area of mill pond: spinning mill, 6 acres; weaving mill, 4 acres.

Approximate depth to which mill pond could be drawn: possibly 2 feet.

Storage capacity on reservoirs: 8 reservoirs and ponds; area about 600 acres; capacity, roughly, 100 000 000 cubic feet.

Storage bought and controlled by predecessors of Vale Mills; cannot hold back natural flow of Salmon Brook, but control probably furnishes the equivalent of an addition of 25 cubic feet per second for three months.

Controlling factors in award: loss of about 5 HP. for greater part of year; settlement made out of court with small expense.

Award did not include any allowances other than for the water or water power.

This settlement was based upon report of engineer and may have been influenced by fact that mills were shut down at the time and offered for sale. The stream, Salmon Brook, on which this power is situated, is a very good one and has been used for power purposes for more than sixty years.

$89.70 PER SQUARE MILE PER FOOT OF FALL, including small allowance for interest and collateral items.

145 New Hampshire, Nashua, Hillsboro County, 1896.

Nashua Manufacturing Company and Jackson Company, Runnell's Bridge, *v.* Metropolitan Water Board.

FULLY DEVELOPED PRIVILEGES ON NASHUA RIVER.

Authority: Charles T. Main, Boston.

BY AGREEMENT, Nashua, $183 750; Jackson, $149 100.

Watershed diverted:

Nashua,	118.23	out of	522.03 square miles.
Jackson,	118.23	,, ,,	527.34 ,, ,,
Runnell's Bridge,	118.23	,, ,,	506.1 ,, ,,

Developed fall:

Nashua,	34.5	feet out of	35.25 feet.	
Jackson,	21.75 ,,	,, ,,	22.30 ,,	
Runnell's Bridge,	10.50 ,,	,, ,,	10.96 ,,	(Nashua Mfg. Co.)
	66.75 ,,	,, ,,	68.51	

$10\frac{1}{4}$ hour power.

Nashua: power fully developed in a very thorough and substantial manner; product, cotton flannels and blankets. Jackson: product, shirtings and cotton flannels. Runnell's Bridge used for storage only, but could be for power if desired.

Watershed: typical New England.

Coal: $4.46 per short ton.

Steam used at Nashua for manufacturing or other purposes.

Water used at Nashua for other purposes than for power.

Wheels installed:

Nashua, 8-5-39-inch; 2-36-inch; 1-66-inch; 3 605 HP. at 75 per cent. efficiency.

Jackson, 5-4-72-inch; 1-30-inch; 1 520 HP. at 75 per cent. efficiency.

Total steam power development:

Nashua, 2 200 HP. nominal; 3 225 maximum.

Jackson, 700 HP.

Total power required to run mill: Nashua, 3 000 maximum.
Jackson, 1 300 ,,

Nearly full amount of steam required to run mill.

Approximate area of mill pond: Runnell's Bridge, 63 acres.

Approximate depth to which pond can be drawn: 4 feet in times of low flow.

585 000 cubic feet of storage reservoirs upon watershed.

Storage controlled so as to be drawn in times of low flow.

Controlling factor in award: desire for amicable settlement.

Award included allowance for rearrangement and addition to steam plants.

NASHUA MANUFACTURING COMPANY, $33.60; JACKSON COMPANY, $58.00, PER SQUARE MILE PER FOOT OF FALL.

146 New Hampshire, Nashua, 1900.

Metropolitan Water Board (of Massachusetts) to City of Nashua, N. H.

NO POWER.

Authority: A. W. Dean, Nashua, N. H.

BY AWARD, $29 000 (exclusive of interest).

Sewage disposal in Nashua River.

Watershed above privilege: 528 square miles.

Watershed taken: 118 square miles.

Insufficient amount of water flowing in river to properly dilute sewage from city. Amount of award based upon cost of construction of intercepting sewers.

SPECIAL DAMAGES.

147 New Hampshire, Tilton, Laconia, and Guilford, July 1, 1889.

William A. Russell, of Lawrence, Mass., and Warren F. Daniels, Franklin, N. H., from Proprietors of Locks and Canals on Merrimac River, Lowell, Mass., and The Essex Company, Lawrence, Mass.

FULLY DEVELOPED PRIVILEGE WITH MILL PROPERTY ON OUTLET OF LAKE WINNEPISSIOGEE.

Authority: W. E. Buck, Worcester, Mass.

SALE, $85 000 (exclusive of interest).

Sold all the stock of Winnepissiogee Lake Cotton and Woolen Manufacturing Company. (See also remarks below.)

Total area of watershed above Lakeport dam: 366 square miles; above East Tilton dam, 428 square miles.

Fall used at East Tilton, 16 feet; at Lakeport, 8 to 12 feet.

12 and 24 hour power.

Watershed: hilly and wooded.

Approximate area of mill pond above Lakeport dam: $71\frac{3}{4}$ square miles; above East Tilton, $7\frac{1}{3}$ square miles.

Available storage depth at Lake Winnepissiogee: 4 feet; Lake Winnisquam (East Tilton), 2 feet.

Storage reservoirs: Smith's and Crooked ponds, 4.85 square miles.

Control of storage very good.

This sale included all property of the Lake Company, and in addition to the above-named water power it included the following:

An interest in one water power at Tilton, N. H., worth	$5 000
An interest in Perley Canal at Laconia, N. H., worth	5 000
Land and buildings at the Weirs, N. H., worth about	4 000

The dam at East Tilton, N. H., is at the outlet of Lake Winnisquam and controls the flow of the Winnepissiogee River from this point

down. The head is about 16 feet, and the Lake Company are under agreement with mill owners below to discharge not less than 250 c.f.p.s. on 24 hour schedule at all times, and control the flow over and above this amount. This power at time of sale was leased and in use for a ground wood-pulp mill, the Lake Company reserving the right to control the flow of water subject to the above requirement.

The dam at Lakeport controls the outlet of Lake Winnepissiogee, and the Lake Company are under agreement with the Laconia mill owners which requires a constant flow of about 250 c.f.p.s. at this point. Here and at Laconia the water is largely used on 10 hour schedule and can be used on either 10 hour or 24 hour schedule at either place without serious trouble, as there is a mill pond above the Laconia dam of 445 acres. The power at Lakeport is subject to two perpetual leases, and aside from these was in use at time of sale to run one hosiery mill, one saw mill, one grist mill, and two small cotton mills, all included in the sale.

$6.75 PER SQUARE MILE PER FOOT OF FALL.

148 New Hampshire, Wolfboro, January 2, 1889.

The Winnepissiogee Lake Cotton and Woolen Manufacturing Company to Nathaniel T. Brewster and James H. Martin of Wolfboro, N. H.

DEVELOPED WATER PRIVILEGE, OUTLET OF SMITH'S AND CROOKED PONDS.

Authority: W. E. Buck, Worcester, Mass.

SALE, $6 000 (exclusive of interest).

Watershed diverted: 24 square miles.

Fall: about 18 feet when dam is full.

Very little fall used or developed.

Character of watershed: rather flat and open.

Approximate area of mill pond: 4.85 square miles.

Working depth of mill pond: 4 feet.

Storage reservoirs upon watershed: Smith's and Crooked ponds only.

Control of storage: good.

Power variable with height of water in lake, but could probably rely on head of 14 feet with flow of about 25 c.f.p.s. for 24 hours.

$13.87 PER SQUARE MILE PER FOOT OF FALL.

149 New York, Bedford, Westchester County, 1906.

Seth Hoyt *v.* City of New York.

DEVELOPED WATER PRIVILEGE.

Authority: G. G. Honness, Pleasantville Station, N. Y.

BY AWARD, $64 000 (exclusive of interest).

Award,	$64 000
Disbursements,	1 512
Counsel fees,	3 215
Interest,	4 304
Total,	$73 031

Character of privilege: grist and saw mill.

Area of watershed: 28.09 square miles.

Watershed diverted: 2.54 square miles of watershed was acquired for reservoir purposes, and this eliminated this power.

Water diverted:

Average run-off per square mile, 32-year record = 1.698 c.f.p.s.
,, driest year, ,, ,, = 0.93 ,,
,, wettest ,, ,, ,, = 2.60 ,,

Fall developed: 22.5 feet out of 32.5 feet.

10 hour power when used as grist mill.

Character of development: grist and saw mill. Of late years feed only was ground. The mill was equipped for the roller flour process. At one time did a wheat-grinding business.

Character of watershed: rolling country devoted to agriculture; not much timber land within drainage area.

Cost of coal:

Anthracite, $6.50 to $7.10 per ton.
Soft coal, 3.75 ,, 4.25 ,, ,,

Electric current from hydraulic plant 6 miles to the north: 10 cents per kilowatt hour.

Wheels installed:

Grist mill	One 22 inch Alcott. ,, 24 ,, Chapman. ,, 18 ,, ,,	Saw mill	One 18-inch Chapman. ,, 48 ,, Flutter. ,, Rose wheel.

Power required to run mill:

Average run-off for 32-year period = 122 HP. theo.
,, driest ,, = 67 ,, ,,
,, wettest ,, = 187 ,, ,,

Area of pond: 2.1 acres.

Working depth: 5.2 feet.

Storage reservoirs: four natural lakes or ponds.

Award included five buildings, the machinery in the mills, and 9.48 acres of ground.

This power was taken by Commissioners of Appraisal in the Cross River Reservoir Proceedings. Awards made by such commissioners for land, etc., taken by the City of New York are notoriously high. Land taken in these proceedings cost the city over $1 000 per acre. The average assessment before the city acquired it was not over $50 per acre. D. S. Brinsmade valued the power alone at $18 000

to $20,000. A fair value for everything would be perhaps $32 000. The $1 000 per acre noted includes all expenses incidental to taking the land, such as fees for claimants' lawyers, witnesses, etc., and commissioners' fees, and legal expenses of the corporation counsel, etc.

$70.00 PER SQUARE MILE PER FOOT OF FALL.

150 New York, Brunswick, Rensselaer County.

City of Troy *v.* Planters' Hoe Company.

PARTIALLY DEVELOPED WATER PRIVILEGE ON "QUACKENKILL" STREAM.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $24 000 (exclusive of interest).

Character of privilege: brick mill, timber dam, used for the manufacture of planters' hoes. (Business at this time was small and decreasing.)

Watershed above privilege: 81 square miles.

Watershed diverted: 17½ square miles.

Amount of water diverted: all from watershed.

Fall: 29 feet, fully developed.

Ordinarily 10 hour power.

Character of watershed: mountainous.

One wheel, 220 HP.; no steam used.

Area of mill pond: small and of no practical use as storage.

Small storage reservoirs upon watershed.

This property, it is said, could have been bought only a year or two before the city took the water for $10 000 for the whole privilege; the city only diverted about one fifth of the water. The company continued business for a year or two after the award was made and then gave up business. The buildings were getting rather poor. This privilege is located on the "Quackenkill" stream. Other cases on the same stream are now being tried under another commission.

$47.25 PER SQUARE MILE PER FOOT OF FALL.

151 New York, Brunswick, Rensselaer County.

City of Troy *v.* J. T. Young and others.

UNDEVELOPED WATER PRIVILEGE ON QUACKENKILL CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AGREEMENT, $6 000.

Area of watershed: 91.3 square miles.

Watershed taken: 17.5 miles.

Fall: 55.1 feet.

Character of watershed: mountainous.

To improve privilege: J. T. Young's and J. A. Clipperly's privileges should be developed together; own only a part of stream, therefore would necessitate purchase of others' rights to about one fourth of stream; would take a long tunnel and power house. No estimate as to cost of development.

Capacity of storage reservoirs: about 58 000 000 cubic feet.

Character of control of storage: controlled by other parties, who use it at privileges below these powers and draw the storage when they need it, regardless of intervening privilege.

Controlling factors in award: value for power purposes; also value of water to farmer for domestic purposes.

In a rocky gorge; would not, however, be very expensive to develop.

$6.23 PER SQUARE MILE PER FOOT OF FALL.

152 New York, Brunswick, Rensselaer County.

City of Troy *v.* J. A. Clipperly and others.

UNDEVELOPED WATER PRIVILEGE ON QUACKENKILL CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AGREEMENT, $1 000.

Watershed above privilege: 91.3 square miles.

Watershed taken: 17.5 square miles.

Fall: 10.6 feet.

Character of watershed: mountainous.

To improve privilege: this privilege and J. T. Young's should be developed together; own only part of stream, therefore would necessitate purchase of others' rights to about one fourth of stream; would take long tunnel and a power house. No estimate as to cost of development.

Storage capacity: 58 000 000 cubic feet.

Character of control of storage: controlled by other parties, who use it at privileges below these powers and draw the storage when they need it regardless of intervening privilege.

Controlling factors in award: value for power purposes; also value of water to farmer for domestic purposes.

In a rocky gorge; would not, however, be very expensive to develop.

$5.40 PER SQUARE MILE PER FOOT OF FALL.

153 New York, Brunswick, Rensselaer County.

City of Troy *v.* Francis Collison.

DEVELOPED WATER PRIVILEGE ON QUACKENKILL CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AGREEMENT, $2 750 (exclusive of interest).

Watershed above privilege: 25.3 square miles.

Water taken: 17.5 square miles.

Fall: 3 feet.

Power used only occasionally for turning grindstone, pumping water for domestic purposes, threshing, etc.

Character of development: small wooden dam. Turbine water wheel with small shed over.

Character of watershed: mountainous.

Water is used for power and domestic use.

One 7 HP. wheel installed.

Privilege is in fairly good condition of repair.

Storage reservoirs upon watershed: about 58 000 000 cubic feet.

Character of control of storage: controlled by other parties, who use it at privileges below these powers and draw the storage when they need it, regardless of intervening privilege.

Controlling factors in award: value for power purposes; also value of water to farmer for domestic purposes.

Is a plant used by a prosperous farmer for uses on his farm to furnish water and power for grindstone, threshers, etc.

$52.38 PER SQUARE MILE PER FOOT OF FALL.

154 New York, Brunswick, Rensselaer County.

City of Troy, *v.* Willard D. Green.

UNDEVELOPED WATER PRIVILEGE ON QUACKENKILL CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AGREEMENT, $1 350.

Watershed above privilege: 18.1 square miles.

Watershed taken: 17.5 square miles.

Water taken: total flow from area diverted, 17.5 square miles.

Fall: 74 feet.

Character of watershed: mountainous.

To improve privilege: dam must be built, conduit about ¼ mile in length, and power plant.

Storage reservoirs about 58 000 000 cubic feet capacity.

Storage controlled by other parties, who used it at privileges below these powers and draw the storage when they need it, regardless of intervening privilege.

Controlling factor in award: prospective value for power purposes.

No allowances for other than water or water power.

Remarks: formerly developed in three separate plants. Dams now all destroyed and power plants entirely obliterated. Cost of development would be large in proportion to amount of power that could be obtained.

$1.04 PER SQUARE MILE PER FOOT OF FALL.

155 New York, Fort Plain, 1899 to 1906.

Fred Loeffler Estate, Morey, Miller, and Yoran *v.* Fort Plain, N. Y.

DEVELOPED WATER POWER PRIVILEGE ON NORTH CREEK (tributary of Garoga Creek).

Authority: Robert E. Horton, Albany, N. Y.

BY AGREEMENT, 1896, Fred Loeffler Estate, $1 000.

BY AWARD, 1897, Frank Morey, $1 350.
Irving Miller, $1 350
L. Yoran, $1 350.

Character of privilege: Loeffler, Morey, Miller, and Yoran were developed water powers, the first-named being a grist mill and the other three, straw-board mills with cheap dams, wooden buildings, old-fashioned machinery, making air-dried board, a few tons per day.

Area of watershed: about 81 square miles. Area of creek above intake: about 4.65 square miles.

Water diverted: approximately 558 800 gallons.

Fall: 18 to 20 feet.

10 hour working day.

Character of watershed: upper drainage area contains lakes artificially regulated. Stream is good water yielder; moderately rolling in topography and with considerable percentage forest; minimum monthly flow about 30 c.f.s.

Wheels installed: existing paper mills usually have from one to three wheels of an average of perhaps from 25 to 40 HP. each.

Area of mill pond: few acres.

Working depth: usually from 1 to 3 feet.

"Several other owners of property on Garoga Creek and on North Creek were paid either as a result of agreement or condemnation proceedings." These payments were chiefly for rights-of-way and for the diversion of water used solely for farming purposes, and the details of these other payments are not sufficiently well known to be of value. "There were no cases where there were any mills in actual" operation or dams constructed except as above stated.

$57.20 PER SQUARE MILE PER FOOT OF FALL.

156 New York, Frankfort, Herkimer County, February, 1905.

Parker & Waterbury *v.* Utica & Mohawk Valley Railroad Company.

DEVELOPED WATER PRIVILEGE.

Authority: Robert E. Horton, Albany, N. Y.

BY AWARD: About $960 (including interest and allowances for collateral items).

Character of privilege: spring in side of sandy hill; outflow pipe to residences in village 400 feet distant. Water supply used by gravity for household, stable, and lawn purposes of the two claimants.

Total watershed: construction of railway cut drained springs to lower level and cut off pipe line.

Water taken: minimum gaged flow of springs 2 500 gallons per 24 hours.

Fall: about 20 feet fall from springs to ground level at residences. Value of water claimed for domestic uses and not for power.

Controlling factors in award: quality, permanence, and convenience of the water supply, and capitalized cost of substituting municipal village supply in place thereof.

SPECIAL CASE. HOUSEHOLD WATER SUPPLY.

157 New York, Lewisboro, Westchester County, 1906.

George Ruscoe *v.* City of New York.

DEVELOPED WATER PRIVILEGE.

Authority: G. G. Honness, Pleasantville Station, N. Y.

BY AWARD, $9 000 (exclusive of interest).

Award,	$9 000
Disbursements,	268
Counsel fees,	450
Cost,	50
Total,	$9 768

Character of privilege: cider mill and saw mill.

Area of watershed: 3.72 square miles.

Watershed diverted: only a small portion above this power, but the taking eliminated this power entirely.

Water diverted:

Average run-off, 32-year record = 1.698 c.f.p.s. per square mile.
,, driest ,, ,, = 0.93 ,, ,, ,, ,,
,, wettest ,, ,, = 2.60 ,, ,, ,, ,,

Fall taken: 7.8 feet out of 7.8 feet.

Mill had not been in use for at least fifteen years.

Character of development: cider and saw mill. Has not been in use of recent years.

Character of watershed: rolling country, devoted to agriculture. Not much timber within the drainage area.

Cost of coal: Anthracite, $6.50 to $7.10 per ton.
Soft coal, $3.75 ,, 4.25 ,, ,,

Electric current from hydraulic plant, 6 miles north, 10 cents per kilowatt hour.

One overshot wheel.

Power of wheels: average run-off with H noted would give 5.6 theoretical HP.

Area of mill pond: very small. Mill had to depend almost entirely on stream flow. Capacity of pond (available), 91 500 gallons.

Award included 4 buildings and machinery in mill and 1.42 acres of land.

This power was taken by Commissioners of Appraisal in the Cross River Reservoir proceedings. Awards made by such commissions for land, etc., taken by the city of New York are notoriously high. Land taken in these proceedings cost the city over $1 000 per acre. The average assessment before the city acquired it was not over $50 per acre. Daniel S. Brinsmade valued the power alone at $18 000 to $20 000. A fair value would be perhaps $32 000. The $1 000 per acre noted includes all expenses incidental to taking the land, such as fees for claimants, lawyers, witnesses, etc., and commissioners' fees and legal expenses of the corporation counsel, etc.

$311.00 PER SQUARE MILE PER FOOT OF FALL.

158 New York, Lewisboro, Westchester County, 1906.
George Hull Estate *v.* City of New York.

DEVELOPED WATER PRIVILEGE.

Authority: G. G. Honness, Pleasantville Station, N. Y.

BY AWARD, $18 000 (exclusive of interest).

At least 20 per cent. to be added to amount of award.

Grist and saw mill.

Watershed above privilege: 16.5 square miles.

Watershed diverted: power entirely eliminated.

Water diverted:

Average run-off per square mile, 32-year record = 1.698 c.f.p.s. per square mile.

Average run-off driest year, 32-year record = 0.93 c.f.p.s. per square mile.

Average run-off wettest year, 32-year record = 2.60 c.f.p.s. per square mile.

Fall: 11.5± feet.

Fall used: 11.5± feet.

10 hour power.

Character of development: feed and a small quantity of sawed lumber.

Character of watershed: rolling country devoted to agriculture; not much timber within drainage area.

Cost of coal: Anthracite, $6.50 to $7.10 per ton.
Soft coal, 3.75 " 4.25 " "

Electric current from hydraulic plant six miles north, 10 cents per kilowatt hour.

Wheels installed: 2 turbine wheels.
1 rose wheel.
1 flutter wheel.

Area of pond: 1.75 acres.

Working depth of pond: 6.2 feet. Storage available, 1 300 000 gallons.

Storage reservoirs: 4 natural lakes or ponds.

Award included three buildings and some land.

This power was taken by Commissioners of Appraisal in the Cross River Reservoir proceedings. Awards made by such commissions for land, etc., taken by the city of New York are notoriously high. Land taken in these proceedings cost the city over $1 000 per acre. The average assessment before the city acquired it was not over $50 per acre. Daniel S. Brinsmade valued the power alone at $18 000 to $20 000. A fair value would be, perhaps, $32 000. The $1 000 per acre noted includes all expenses incidental to taking the land, such as fees for claimants' lawyers, witnesses, etc., and commissioners' fees and legal expenses of the corporation counsel, etc.

$94.70 PER SQUARE MILE PER FOOT OF FALL.

159 New York, Little Falls, 1899 to 1902.

Various millers on Spruce Creek against City of Little Falls.

DEVELOPED WATER PRIVILEGE ON SPRUCE CREEK (tributary to East Canada Creek near Dolgeville, N. Y.).

Authority: Robert E. Horton, Albany, N. Y.

SMALL AMOUNTS (a few hundred dollars each) to several small mills.

Character of privileges: small grist and saw mills and wood-working establishments.

Total area of watershed: above Little Falls, city intake and storage dam, 36.2 square miles; above mouth, 50.4 square miles.

Usually 10 hour power used; for custom saw and grist mills it was frequently less.

Character of watershed: rolling highland, partly in cultivation, but containing large percentage of forest and swamp land. Rainfall about 40 inches per annum. Soil generally impervious, but stream an excellent water yielder.

Usually one or two old-fashioned inefficient wheels of small power.

Area of mill pond: slight.

Working depth of mill pond: 1 or 2 feet.

Storage reservoirs not on watershed at time of diversion.

City built water-works conduit intended to deliver about 4 000 000 gallons per day; also a storage reservoir of 150 000 000 gallons capacity at Salisbury, the intention being to use this as compensation reservoir and let out in the spring an amount equal to the ordinary low water flow, and also to take therefrom water supply required for city of Little Falls, the conduit being usually operated at full capacity.

(NOTE. — For further description of drainage area, etc., see State Engineer's reports for 1903, page 77.)

"In looking over the reports for the years from 1899 to 1905 I find that the following payments were made. I do not know whether they were settlements of awards. With the exception of McDougal & Elwood and Beardslee, all seem to have been farmers."

1899	J. H. Clemens,	$75.00
	G. W. Smith,	375.00
1900	McDougal, Elwood, Bingham *et al.*,	10 000.00
	E. C. Fairchild,	350.00
	C. R. Avery,	100.00
1901	Louisa Edwards,	200.00
1903	Helen Hughes,	60.00
	Beardslee,	5 500.00*
	Corey and Fish,	350.00
	Shedd, Munder, and six others,	1 865.82
	H. D. Wright, attorney for several cases,	1 450.00
1905	H. D. Wright, attorney for fifteen cases,	3 733.13

DATA INCOMPLETE.

160 New York, Olive Bridge, Ulster County, March, 1908.

Ferdinand Ehrlich *v.* Board of Water Supply, City of New York.

UNDEVELOPED WATER PRIVILEGE ON ESOPUS CREEK.

Authority: Robert E. Horton, Albany, N. Y.

NO DAMAGE.

Character of privilege: undeveloped fall, chiefly in natural waterfall in shale rock gorge.

Total watershed: about 235 square miles.

Fall: 24 feet.

Character of watershed: Precipitous, largely forest covered. A very torrential stream, minimum flow about 20 c.f.s.

Controlling factors in award: claimant asked $300 000 to $500 000 award on assumption of clear title to entire fall and in view of fact that in conjunction with property and adjacent thereto is available blue stone aggregating millions of dollars in value,

* And $3\frac{1}{2}$ inches water over 18-foot weir.

which can be economically quarried and milled by water power. Commission did not uphold claimant's title and adjudged no value for any water power which he owned.

City proposed to build Ashokan dam at this site to divert practically entire drainage area and flow.

(NOTE.—For further description of drainage area, etc., see State Engineer's Report for 1903, page 132; also in later reports.)

NO DAMAGE.

161 New York, Ithaca, Tompkins County.

UNDEVELOPED WATER PRIVILEGE ON TAUGHANNOCK CREEK.

Authority: Leonard Metcalf, Boston, Mass.

AWARD, $80 000.

Watershed: 67 square miles.

Fall: 543 feet.

$2.21 PER SQUARE MILE PER FOOT OF FALL.

162 New York, Pittstown, Rensselaer County.

City of Troy *v.* William Yates.

DEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $3 200 (exclusive of interest).

$3 770.72 (including interest, etc.).

Saw mill.

Watershed above privilege: $1\frac{3}{4}$ square miles.

Watershed diverted: $1\frac{3}{4}$ square miles.

Water taken: entire flow of stream.

Fall: 20 feet.

10 hour power, more or less, as custom work demands.

Character of development: earth dam and small mill, 15-inch McCormick wheel, sawed about 300 000 feet BM. per annum.

Character of watershed: upper third mountainous and well wooded; lower two thirds open and hilly, or rolling and largely cultivated, or pasture land.

One wheel installed.

Area of mill pond: small and not capable of storing sufficient water to run mill for several hours.

Award included allowance for land and houses: 2.2 acres of land, but no other buildings.

The earth dam had been washed out the year before the city condemned it. The mill was old and not in very good repair.

$91.43 PER SQUARE MILE PER FOOT OF FALL, including land and houses.

163 New York, Pittstown, Rensselaer County.

City of Troy, *v.* Hiram File.

DEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $17 000 (exclusive of interest).
$20 031.95 (including interest, etc.).

Saw and grist mill.

Watershed above privilege: 10 square miles.

Watershed diverted: 10 square miles.

Water taken: entire flow of stream.

Fall: 24 feet.

Fall developed: 24 feet.

10 hour power used more or less, as work demands.

Character of development: rubble masonry dam, two separate mills, wooden penstock to each; saw mill from 50 000 to 400 000 feet sawed timber per annum. Grist mill custom grinding.

Charaeter of watershed: upper third mountainous and well wooded; lower two thirds open and hilly or rolling and largely cultivated or pasture land.

Two wheels installed, one in each mill; no steam used.

Area of mill pond: small and not capable of storing sufficient water to run mill for several hours.

Award included allowance for land and houses: 34 acres of land, a large house, and a tenement house, all in good repair.

Privilege was located within the site of the city's proposed reservoir and all the property was in very good condition.

Did considerable grist mill and saw business. Located in small villages and in good farming district.

$70.80 PER SQUARE MILE PER FOOT OF FALL, *including* land and houses.

164 New York, Rochester, Counties of Monroe, Livingston, and Ontario; award, 1886; settlement, 1892–5.

City of Rochester, County of Monroe, N. Y., 25 owners of water rights, old conduit; 23 owners of water rights, new conduit.

DEVELOPED WATER PRIVILEGES UPON HEMLOCK AND CANADICE LAKES.

Authority: E. A. Fisher, Rochester, N. Y.

BY AWARD, exclusive of interest, $111 123.64; including interest and costs $123 376.98 (account of old conduit, 9 000 000 gallons per day from Hemlock Lake, June 17, 1886).

BY AGREEMENT, exclusive of interest, $67 250 (account of new conduit, remainder, about 20 000 000 gallons per day from both lakes).

Character of privilege: saw mills, flour mills, wood working mills, paper mills, cider mills, and machine shops.

Watershed above privilege: 129 466 acres = 202.29 square miles.

Watershed diverted: 39 952 acres = 62.42 square miles.

Water diverted: first, old conduit, 9 000 000 gallons per day; second, whole flow of both lakes, exclusive of 9 000 000 gallons already taken, about 20 000 000 gallons per day additional. (See table attached.)

10 hour power generally used.

Character of development: lumber, flour, wood working, paper, and cider mills, machine shops, factories, etc.

Character of watershed: hilly.

Coal estimated at $3.50 per ton, first award.

Electric current not used at that time.

Steam is used to some extent.

Water is now used for municipal purposes entirely.

Storage upon watershed: there are two lakes upon the watershed; Hemlock Lake, about 7 miles long, having an area of about 3 square miles, and Canadice Lake, about 3 miles long, having an area of about 1 square mile.

Character of control of storage: originally by digging out channel of Hemlock Lake when water was low.

Controlling factor in award: reduction of water supply required installation of steam power.

The proceedings in the matter of the application of the city of Rochester to acquire the permanent and perpetual right to draw from Hemlock and Canadice lakes an amount of water for the use of said city and its inhabitants not exceeding 9 000 000 of gallons per day, referred to herein as the *old conduit, — 9 000 000 gallons per day,* — were very long drawn out, and the matter of damage to mill owners was gone into very thoroughly by the late Mr. J. Nelson Tubbs and by Mr. Emil Kuichling. The printed proceedings in the Court of Appeals cover about 1 300 pages. It is difficult, however, to collect out of this vast amount of material definite statements that will answer the questions herein. (See table attached.)

$43.50 PER MILLION GALLONS DAILY PER FOOT OF FALL, first diversion.

$11.90 PER MILLION GALLONS DAILY PER FOOT OF FALL, second diversion.

STATEMENT GIVING NAMES OF OWNERS OF WATER-POWER RIGHTS ON HEMLOCK LAKE OUTLET AND HONEOYE CREEK, ETC.

Name of Owner.	Kind of Right.	Wheels. No.	Wheels. Diameter in Inches.	Wheels. Class.	Effective Head in Feet.	Cubic Feet per Minute Required to Operate Wheels to Full Capacity.
Salsich & Ruland	2d	1	30½	Leffel	12	1 204
Barton & Williams	1st	1	30½	Leffel	17½	1 453
J. W. Townsend	1st	2	55, 36	Bodine, Risdon	7½	4 061
Cora J. Trimmer	1st	1	36	American	14	1 459
Amos Lotee	1st	2	23, 35	Leffel	10½	2 133
Frank A. Booth	1st	1	30½	Leffel	18	1 475
Davis & Fairchild	2d	1	24	York	13½	800
James A. Stillman	57% of 3d	1	28	York	13	1 057
Eunice A. Lloyd	43% of 3d	1	24	Leffel	13	785
Edwin E. Bond	2d	2	40, *30½	Leffel	12	3 287
Lewis Johnson or J. Ideson	3d	1	30½	Leffel	10	1 099
John Ideson	1st	2	42, 30	Tait	14	3 753
W. R. & E. L. Yorks	1st	1	Breast	wheel	6	1 714
George R. Smith	1st	2	†30½, 20 ft.	Leffel, Overshot	22	1 667
Smith & Johnson	2d	2	30½, 17½	Leffel	22	2 163
M. & S. Pierce	2d	1	26½	Leffel	16	1 043
Smith & Pride	1st	2	35, 35	Leffel	16	3 662
Hunt Brothers	1st	2	30½	Leffel	11	1 153
Lee & Cook	1st	2	30, 30	Greig, Tait	10½	2 266
Weaver & Foote	1st	1	48	Leffel	9½	2 677
B. G. Weaver	2d	1	30	American	9½	905
J. W. Day	1st	2	60, 60	Nelson	6	7 894

165 New York, Rome, 1903 and 1904.

Whitestown Water Company *v.* City of Rome, N. Y.

UNDEVELOPED WATER PRIVILEGE ON EAST BRANCH OF FISH CREEK BETWEEN TABERG AND POINT ROCK, N. Y.

Authority: Robert E. Horton, Albany, N. Y.

* Bond's wheel given as 30½ inches is really 26½ inch special, but uses the same amount of water as a 30½-inch wheel.

† George R. Smith's wheel is a 30½ inch special.

BY AWARD, $7 200 (including value of farm land).

Character of privilege: undeveloped fall in rock gorge.

Total watershed: 135 square miles.

Watershed diverted: City of Rome appropriated Chism farm fronting on creek, thus dividing fall on claimant's property. City had acquired right from legislature to divert water, bed of stream being included in an Indian reservation, but right to use water belonged to owners of water frontage, except as required by state for public purposes.

Water diverted: actual amount did not enter question. Population supplied about 15 000, but city assumed right to take entire minimum flow of 30 000 000 gallons per twenty-four hours.

Fall: 273 feet.

Character of watershed: southwestern Adirondack slope, largely forest covered, much swamp area. Precipitation, 50 inches or 60 inches per year.

Coal about $2.60 per ton in adjacent cities.

Power development: proposed 2 500 HP.

Supplementary steam or electricity necessary; proposed by claimant, but excluded from testimony by commission.

Development requires dam 55 feet high in rock gorge, about 100 feet wide; also conduit 18 140 feet long.

Proposed dam would give pondage area of a few acres.

It was assumed pond would be drawn several feet.

Controlling factors in award: claimant owns lands bordering streams opposite which there was a total fall of 273 feet. City appropriated one parcel for purpose of building intake. Fall below this parcel, 111 feet. Claimant estimated value of property as a single unit at various rates as high as $700 000. He claimed that what was left below city's appropriation was worthless for development; that value of upper fall alone (162 feet) was only $200 000 or $300 000, leaving estimated damage of several hundred thousand dollars, amounts varying according to different experts. City's experts, including writer, estimated none of the power to be of any value for immediate development. I estimated its present worth undeveloped, assuming that it would be profitable for development in ten of fifteen years, to be $7 200, which amount was awarded by commission.

$0.20 PER SQUARE MILE PER FOOT OF FALL.

166 New York, Saranac Lake, 1902.

Benjamin Hall *v.* State of New York.

DEVELOPED WATER PRIVILEGE ON SARANAC RIVER, N. Y.

Authority: Robert E. Horton, Albany, N. Y.

Claimant adjudged not having any water power of value.

Character of privilege: 8 feet head created by dam giving large storage and controlling lake.

Area of watershed: 157.5 square miles.

Character of watershed: eastern Adirondack forest. Rainfall, 30 inches to 36 inches; run-off regulated by lakes.

Area Saranac Lake: 14.5 square miles.

Controlling factors in award: State Court of Claims on several trials gave claimant awards, but each time case was sent back for re-trial on the ground of award not being in accordance with facts in evidence and without proper legal foundation; that state had acquired title to whatever land it flooded and that no water power of any value was destroyed. Case was finally dropped.*

Twice sent back for re-trial.

NO DAMAGE.

167 New York, Schaghticoke, Rensselaer County.

City of Troy *v.* James Evans.

DEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $12 000 (exclusive of interest).

$14 140.20 (inclusive of interest, etc.).

Grist mill.

Watershed above privilege: 69 square miles.

Watershed diverted: 67 square miles.

Fall: 18 feet.

10 hour power more or less, as custom work demands.

Character of development: timber dam, custom grinding only.

Character of watershed: upper one third mountainous and well wooded; lower two thirds open and hilly or rolling and largely cultivated or pasture land.

One wheel installed. No steam.

Area of mill pond: small and not capable of storing sufficient water to run mill for several hours.

Award included damages to dwelling and land connected therewith; small amount of land.

Privilege was located below the city's dam about one mile.

Did a considerable grist and saw mill business.

Located near small villages and in good farming districts.

$13.70 PER SQUARE MILE PER FOOT OF FALL, including damages to land and buildings, and award for No. 168.

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* Award on first trial: land, 59.2 acres at $1.50 acre	$88.79
Dam site and water power	2 000.00
Total, plus interest	$2 088.79

168 New York, Schaghticoke, Rensselaer County.

City of Troy *v.* George Burton.

DEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK. UNUSED.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $4 500 (exclusive of interest).

$5 302.58 (inclusive of interest, etc.).

Saw mill and old flax mill not used for several years.

Watershed above privilege: 69 square miles.

Watershed taken: 67 square miles.

Fall: 18 feet.

Fall used: 18 feet.

10 hour power, more or less, as custom work demands.

Character of development: custom work only; use dam in connection with another mill.

Character of watershed: upper one third mountainous and well wooded; lower two thirds open and hilly or rolling, and largely cultivated or pasture land.

Two wheels installed, one in each mill. No steam.

Area of mill pond: small and not capable of storing sufficient water to run mill for several hours. No storage reservoirs.

Award included damages to dwelling and land connected therewith and small amount of land. Privilege was located below the city's dam about one mile. The old flax mill had not been used for several years before city took water, and sawmill was not in good repair, although they did some custom sawing there.

INCLUDED WITH NO. 167.

169 New York, Schaghticoke, Rensselaer County.

City of Troy *v.* Tibbitts Estate.

UNDEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $22 000.

Character of privilege: Undeveloped, extends along stream for about two miles.

Watershed above privilege: about 75 square miles.

Watershed taken: 67 square miles.

Water diverted: total flow of stream from watershed diverted.

Fall: 150 feet.

Character of watershed: extreme upper portion mountainous; lower part, or probably five sixths of whole, is hilly, rolling country; about $12\frac{1}{2}$ per cent. wooded.

To improve privilege: dam must be built and long conduit, power plant, etc. No estimate made of cost of development, so far as known.

No storage reservoirs upon watershed.

Controlling factors in award: Prospective value for power purposes, also depriving farm lands adjacent to stream from water.

At some time in the past there were one or two mill powers developed on this property, but the only visible signs of them now are the remains of portions of the end embankments of the dams.

$2.19 PER SQUARE MILE PER FOOT OF FALL.

170 New York, Schaghticoke, Rensselaer County.

City of Troy *v.* Theodore Button.

UNDEVELOPED (BUT EASY TO DEVELOP) WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $16 000 (exclusive of interest); including interest, $18 851.06.

Watershed above privilege: about 78 square miles.

Watershed taken: 67 square miles.

Amount of water taken: total flow of stream from watershed.

Fall: 40 feet.

Character of watershed: extreme upper portion mountainous; lower part, or probably five sixths of whole, hilly, rolling country; about 12½ per cent. wooded.

To improve privilege, dam and power plant must be built.

Controlling factors in the award: prospective value for power purposes and damage to farm lands adjacent, caused by loss of water diverted.

This power could be very easily developed. The fall is over a ledge of rock, good foundations for dam and power plant. Fall nearly vertical. Length of dam not over 150 feet. Would have no storage. Power developed would, therefore, fluctuate considerably in amount.

$5.97 PER SQUARE MILE PER FOOT OF FALL.

171 New York, Schaghticoke, Rensselaer County.

City of Troy *v.* M. F. Hoag.

UNDEVELOPED WATER PRIVILEGE ON TOMHANNOCK CREEK.

Authority: E. L. Grimes, Troy, N. Y.

BY AWARD, $1 200.

Watershed above privilege: about 80 square miles.

Watershed taken: 67 square miles.

Amount of water taken: total flow of stream from watershed diverted.

Fall: 8 feet.

Character of watershed: extreme upper portion mountainous; lower part, or probably five sixths of whole, is hilly, rolling country, about 12½ per cent. wooded.

To improve privilege: dam must be built and power plant installed at dam.

Controlling factors in award: prospective value for power purposes and damage to farm adjoining stream occasioned by loss of water diverted.

This power was at one time developed, but only a few visible remains of the old dam exist.

$2.24 PER SQUARE MILE PER FOOT OF FALL.

172 New York, Troy.

City of Troy *v.* James Hislop.

DEVELOPED WATER PRIVILEGE ON POESTENKILL CREEK.*

Authority: E. L. Grimes, Troy, N. Y.

BY AGREEMENT, $5 000.

Watershed above privilege: 96 square miles.

Watershed taken: 17.5 square miles.

Theoretical fall: 12 feet.

Fall used: 12 feet.

10 hour power.

Character of development: timber dam, turbine wheel, power used in foundry.

Character of watershed: mountainous.

One 60-inch Leffel wheel, 12-foot head, installed.

Privilege in fairly good condition of repair.

Capacity of storage reservoirs: 58 000 000 cubic feet.

Character of control: controlled by other parties, who use it at privileges below these powers and draw the storage when they need it, regardless of intervening privilege.

Controlling factors in award: value for power purposes; also value of water to farmer for domestic purposes.

This power is near the mouth of the stream and at high water in the river into which the stream enters the water sets back up the stream, entirely submerging the dam of this power, and the total fall is only available when the river is at its lowest stages. Probably about three months in the year total head is not available.

$23.80 PER SQUARE MILE PER FOOT OF FALL.

* To which the Quackenkill Creek is tributary.

173 New York, Utica, 1902.

William G. Weaver *et al.* *v.* Consolidated Water Company of Utica, N. Y.

UNDEVELOPED WATER PRIVILEGE ON REELS CREEK (entering Mohawk River from the north at Utica).

Authority: Robert E. Horton, Albany, N. Y.

No award for Water Power. No Damage.

Character of privilege: undeveloped falls and rapids in narrow rocky gorge about four miles in length below water company's intake.

Watershed diverted: referee gave water company right to divert about 5 400 000 gallons per day during months of November to April inclusive, but enjoined company against diversion during summer months; 20-inch cast-iron pipe on grade of 2.84 feet per thousand feet.

Fall taken: farms along stream pooled their interests, except that fall on each farm was assumed to be separately developed by one or more dams.

Name of Dam.	Drainage Area. Square Miles.	Amount of Fall. Total Head. Ft.
No. 1 Johnson,	5.6	17.5
No. 2 ,,	6.5	19.75
No. 3 ,,	7.1	17.5
Turnbull,	7.2	8.0
Marsh,	7.3	10.5
Upper Coventry,	7.7	15.5
Wells,	8.2	32.5
No. 2 Coventry,	8.3	25.0
No. 3 Coventry,	9.1	10.5

Character of watershed: pasture land, with steep slopes and numerous wooded gulleys, underlaid by shale rock, very torrential.

Controlling factors in award: claimant assumed that available power could be obtained for manufacture or electrical transmission by constructing dams. Defense successfully overthrew this contention by showing small power available, high cost of development, etc. Referee adjudged the water diverted to be available for agricultural uses only.

(NOTE. — For further description of drainage area, etc., see State Engineer's reports for 1902, page 136; 1903, page 94.)

SPECIAL CASE. NO AWARD.

174 New York, Watertown, August, 1908.

H. Remington & Sons Pulp and Paper Company *v.* Board of Water Commissioners, Watertown, N. Y.

UNDEVELOPED WATER PRIVILEGE one-half mile below village of Black River, Jefferson County, N. Y.

Authority: Robert E. Horton, Albany, N. Y.

NO AWARD, damages being adjudged nominal.

Character of privilege: rapids on limestone rock on Black River comprising about 12 feet fall originally, the upper 8 or 10 feet on land owned on both sides of stream by claimant; also 2 to 4 feet on land owned on one side by claimant, on opposite side by city of Watertown.

Total watershed: about 1 875 square miles.

Character of watershed: western Adirondack slope. Minimum flow 700 to 800 c.f.s., being partially regulated by storage.

Controlling factors in award: referee held that interference or backwater occurred only on portion of stream where city already owned to center of channel, that it was impossible for claimant to develop his half of flow and fall in this portion of river without technical trespass or interference with city's rights, hence damage to him by obstruction of fall by city's dam was adjudged nominal.

Dams built and owned by the city some distance below claimant's property backed water on to the portion of the privilege where claimant owned on one side of river only. Court held that damages, if any, should be awarded on basis of amount of head or fall destroyed at the ordinary stage of stream. This was agreed upon by both parties in case to correspond to flow of 2 300 to 2 500 c.f.s. An amount of interference for this flow was estimated by claimant at 4.2 feet, and by writer, for defendant, at 2.17 feet. Power in question was undeveloped, but could be used in conjunction with plaintiff's pulp mill and electric plant located a few hundred feet upstream.

(NOTE. — For further description of drainage area, etc., see State Engineer's reports for 1902, page 36; 1906, page 36, supplement.)

NO DAMAGE.

175 North Carolina, Durham, Durham County, 1901.

Geer, Cox & Christian *v.* The Durham Water Company.

DEVELOPED WATER PRIVILEGES.

Authority: Durham (N. C.) Water Company.

BY AWARD, $4 000 (exclusive of interest).

Including interest and allowances, $6 000.

Water rights.

Area of watershed: 8 by 15 miles.

Amount of water diverted: 1 000 000 gallons in twenty-four hours; used by Durham Water Company to supply city.

Fall used: 11 feet at Durham Water Company pump station.

Power used: winter, by water twenty-four hours per day; summer, have run by steam at Durham Water Company's pump station.

Character of development: grist mill.

Character of watershed: principally wood land, sparsely settled.

Coal: $4.50 per 2 000 pounds.

Two wheels installed.

Area of mill pond: 1 mile by 200 feet.

Working depth: about 6 feet.

Controlling factor in award: diverting water from stream for city use.

$364.00 PER MILLION GALLONS DAILY PER FOOT OF FALL.

176 Pennsylvania, Bradford, McKean County, 1906.

City of Bradford *v.* C. A. Douglas.

DEVELOPED WATER PRIVILEGES.

Authority: F. W. Dalrymple, Bayonne, N. J.

BY AWARD, $1 plus court costs. Later Purchase, $15 000.

Grist mill with dam and water power.

Watershed above privilege: 104 square miles.

Watershed taken: 14 square miles.

Water diverted: about 1 500 000 gallons per day.

Fall: 9½ feet.

10 hour power.

Character of development: dam with turbines, grist mill.

Character of watershed: hilly and largely wooded.

Coal: $2.50 per 2 000 pounds.

Two wheels installed.

40 HP. required to run mill.

To improve the privilege an auxiliary steam plant should be put in. Cost, $15 000.

Approximate area of mill pond: 12 acres.

Working depth of mill pond: 4 feet.

The city afterwards bought the mill dam and pond for $15 000 and took out the dam as a nuisance.

AWARD, NOMINAL: PURCHASE, $112.77 PER SQUARE MILE PER FOOT OF FALL, including dam and mill.

177 Pennsylvania, Borough of Media, Delaware County, 1903.

Henry T. Kent *v.* Borough of Media.

PARTIALLY DEVELOPED WATER PRIVILEGE.

Authority: Edward H. Hall, Media, Penn.

BY AWARD,* $7 585.25 (including interest at 6 per cent. from April, 1900).

Character of privilege: right to divert 1 500 000 gallons of water continuously through twenty-four hours.

Watershed above point of diversion: 29.9 square miles. At plaintiff's mills, 33 square miles.

Water to be taken: 1 500 000 gallons in twenty-four hours. Only from 500 000 to 800 000 was being actually diverted at time of trial.

Fall: 25 feet.

Fall used: 23½ feet.

10 hour power.

Character of development: there were two mills, one on each side of creek. West side mill was operated by one 18-inch Rodney Hunt wheel and was a weave mill requiring about 40 HP. Steam was used for washing and dyeing; on the opposite end of the line shaft was a 60 HP. upright engine, which was used when water was low. The east side mill had two 21-inch horizontal Rodney Hunt wheels and 125 to 150 HP. Corliss engine. Steam was required in both mills. Boiler capacity in west side, 80 HP., and in east side, 140 HP. In east side engine and wheels were geared on same shaft and run together. It required about 125 HP. to operate east side mill, which manufactured woolen and worsted.

Coal: $3.50 per 2 240 pounds at boilers, Georges Creek bituminous; hauling from railroad station cost 60 cents per ton.

Steam is used in both mills for washing, dyeing, etc.

A small quantity of water is used for other purposes.

One 18-inch Rodney Hunt horizontal wheel, 50 HP., at 75 per cent. efficiency.

Two 21-inch Rodney Hunt horizontal wheels, 142 HP.

Steam and water power development: 342 HP.

Total power required to run mill: west side, about 40 HP.; east side, about 125 to 140 HP.

Capacity of pond: 6 000 000 gallons on an 18-inch draw.

Working depth of mill pond: 18 inches. No substantial storage.

In my judgment, controlling factor with the jury was rate of interest and cost of producing lost power by steam, the jury being of the opinion that the dam of Kent was sufficient to hold the night flow and discharge it during the ten working hours.

This was a condemnation proceeding, the jury of view awarded $3 500; on the first trial before the court and jury a verdict was had for $11 500. A new trial was awarded, and on the second trial the verdict was for $7 585.25. Of course under our laws, this being a condemnation proceeding, the damage is the

* $6 500 approximately, excluding interest.

difference in the market value before and after the diversion. The experts who fixed the damage for the defense made it about $2 400, based on capitalizing at 6 per cent. the cost of supplying the lost power by steam, the estimate being that the water diverted would give 4.6 HP. on the wheel shaft and that for four and a half months in the year the stream flow would be sufficient to run the wheels and would not be affected by the diversion. Counsel for mill owner claimed that the storage being sufficient to hold the flow, instead of the diversion amounting to 4.6 HP., it would be 2.4 times 4.6 HP., or 11.52 HP.

$173.33 PER MILLION GALLONS DAILY PER FOOT OF FALL.

178 Pennsylvania, Crum Lynn, Delaware County, 1895.

Lee & Longbottom, Crum Lynn Mills *v.* Springfield Water Company.

DEVELOPED PRIVILEGE ON CRUM CREEK.

Authority: J. W. Ledoux, Philadelphia.

BY AWARD, $3 500.

Woolen mill run by vertical Leffel water wheels and Corliss engines.

Watershed diverted upon Crum Creek: 29.5 square miles out of 34.9 square miles.

Developed fall: 13.5 feet out of 13.5 feet.

Pondage: 1 125 000 gallons.

10 hour power.

Average flow million gallons per twenty-four hours, including floods: 38.5.

Available flow per hour, including pondage, but with floods cut off: 18.5 m.g.d.

Continuous horse-power diverted: 3.56.

Horse-power after diversion: 28.2.

Watershed: 40 per cent. wooded; balance, farming land.

Coal: $2.50 per ton (low cost due to nearness of two railroads).

Amount of water diverted: 2 000 000 gallons per twenty-four hours.

$130.00 PER MILLION GALLONS DAILY PER FOOT OF FALL.

$8.50 PER SQUARE MILE PER FOOT OF FALL.

Pennsylvania, Springfield, Delaware County, 1904.

Palmers Mill *v.* Springfield Water Company.

PRIVILEGE DEVELOPED ON CRUM CREEK.

Authority: J. W. Ledoux, Philadelphia.

BY SALE, $10 000.

Flour mill run by vertical water wheels and no steam.

Watershed diverted upon Crum Creek: 25 out of 25 square miles.

Developed fall: 10 feet out of 10 feet.

10 hour power.
Watershed: 40 per cent. wooded; balance, farming land.
Coal: $4 per ton.

Private purchase including farm and buildings, having a market value of at least one half of purchase price.

$40.00 PER SQUARE MILE PER FOOT OF FALL, INCLUDING FARM AND BUILDINGS.

Say, $20.00 PER SQUARE MILE PER FOOT OF FALL, EXCLUDING BUILDINGS.

180 Pennsylvania, Springfield, Delaware County, 1895.
Sam Lewis, Lapidea Mills *v.* Springfield Water Company.
ABANDONED PRIVILEGE, CRUM CREEK.
Authority: J. W. Ledoux, Philadelphia.
BY AWARD, $2 700.

Watershed diverted upon Crum Creek: 21.9 square miles out of 33.7 square miles.
Bone mill ruins; not in use for many years.
Developed fall: 11 feet out of 11 feet.
Pondage: 1 900 000 gallons.
Originally 10 hour power.
Average flow million gallons per twenty-four hours, including floods: 37.7.
Available flow, including pondage, but with floods cut off: 20.2 m.g.d.
Continuous horse-power diverted: 2.9.
Horse-power after diversion: 25.1.
Watershed: about 40 per cent. wooded; balance, farming land.
Coal: $2.80 per ton (low cost due to railroad siding).
Amount of water diverted: 2 000 000 gallons per twenty-four hours.

$123.00 PER MILLION GALLONS DAILY PER FOOT OF FALL.

$11.20 PER SQUARE MILE PER FOOT OF FALL.

181 Pennsylvania, Springfield, Delaware County, 1895.
W. S. P. Shields, Avondale Mills *v.* Springfield Water Company.
ABANDONED PRIVILEGE ON CRUM CREEK.
Authority: J. W. Ledoux, Philadelphia.
BY AGREEMENT, $3 500.

Watershed diverted upon Crum Creek: 29.5 square miles out o 33.7 square miles.
Developed fall: 14 feet out of 14 feet.
Pondage: 2 600 000 gallons.

Originally 24 hour power.

Average flow million gallons per twenty-four hours, including floods: 37.1.

Available flow, including pondage, but with floods cut off: 21.5 m.g.d.

Continuous horse-power diverted: 3.69.

Horse-power after diversion: 34.6.

Watershed: 40 per cent. forest; balance, farming land.

Coal: $2.80 per ton (low cost due to railroad siding).

Amount of water diverted: 2 000 000 gallons per twenty-four hours.

Paper mill had been burned for many years.

$8.48 per Square Mile per Foot of Fall.

$125.00 per Million Gallons Daily per Foot of Fall.

182 Pennsylvania, Springfield, Delaware County, 1895.

Albert Lewis, Wallingford Mills *v.* Springfield Water Company.

DEVELOPED PRIVILEGE ON CRUM CREEK.

Authority: J. W. Ledoux, Philadelphia.

BY AWARD, $10 000.

Watershed diverted at Springfield Water Company's plant on Crum Creek: 29.5 square miles.

Drainage area above Wallingford Mills: 31.9 square miles.

Developed fall: 10 feet out of 10 feet.

Textile mill run by vertical Leffel water wheels and Corliss engines.

Pondage: 1 900 000 gallons.

10 hour power.

Average flow million gallons per twenty-four hours, including floods: 35.1.

Available flow, including pondage, but with floods cut off: 19.3 m.g.d.

Continuous horse-power diverted: 2.64.

Horse-power after diversion: 21.4.

Watershed: about 40 per cent. wooded; balance, farm land.

Coal: $3.50 per ton.

Water diverted: 2 000 000 per twenty-four hours.

$33.90 per Square Mile per Foot of Fall.

$500.00 per Million Gallons Daily per Foot of Fall.

183 Rhode Island, Cumberland, Providence County, 1905. (Woonsocket Cases No. 1.)

Valley Falls Company (Albion Mill) *v.* City of Woonsocket.

VERY SUBSTANTIAL AND WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 429 square miles.
Fall: 12.69 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: variable New England.
Coal: $4.20 per 2 000 pounds.
Steam is used for heating and slashing.
Four wheels installed: 2 Holyoke, 54-inch; 1 Leffel, 52-inch; 1 K. & L., 108-inch.
Power of wheels: 700 HP.
Total steam power: 400 HP.
Total power required: 850 HP.
Area of pond: 30 acres.
Working depth: perhaps 1 foot.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

184 Rhode Island, Cumberland, Providence County, 1905. (Woonsocket Cases No. 2.)

Lonsdale Company, Ashton, *v.* City of Woonsocket.

SUBSTANTIAL AND WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 433 square miles.
Fall: 9.50 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: variable New England.
Coal: $4.11 per 2 000 pounds.
Steam is used for heating and slashing.
Water is used for boiler feed purposes.
Four wheels installed: 375 HP.
Total steam: 500 HP.
Total power required: 825 to 850 HP.
Area of pond: 40 acres.
Working depth: 1 foot to 18 inches.

SEE NO. 214, "WOONSOCKET CASES."

185 Rhode Island, Lincoln, Providence County, 1905. (Woonsocket Cases No. 3.)

Lonsdale Company, No. 1, *v.* City of Woonsocket.

WELL-DEVELOPED AND VERY SUBSTANTIAL PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 441 square miles.
Fall: 23.28 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: variable New England.
Cost of coal: $4.11 per 2 000 pounds.
Steam is used for heating, drying, bleaching, etc.
One pair Hercules wheels installed: 410 HP.
Total development: 500 HP.
Power required: 650 HP.
Area of pond: 100 acres.
Working depth: perhaps 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

186 Rhode Island, Cumberland, Providence County, 1905. (Woonsocket Cases No. 4.)

Lonsdale Company, No. 4 Mill, *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 441 square miles.
Fall: 14.03 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: variable New England.
Coal: $4.11 per 2 000 pounds.
Steam is used for slashing.
Water is used for boiler feed and condenser.
Three wheels installed: 630 HP.
Total power development: 750 HP.
Total power required: 1 250 HP.
Area of mill pond: 180 acres.
Working depth: perhaps 1 foot.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

187 Rhode Island, Valley Falls, Providence County, 1905 (Woonsocket Cases No. 5.)

Albion Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 443 square miles.
Fall: 14 109 feet.

10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: variable New England.
Six wheels installed: 1 033 HP.
Total power development: over 1 200 HP.
Power required: 1 000 HP.
Area of pond: 215 acres.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

188 Rhode Island, Central Falls, Providence County, 1905. (Woonsocket Cases No. 6.)

Stafford Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 9.787 feet.
Character of development: well-developed cotton mill.
Coal: $4 per 2 000 pounds.
Steam is used for heating purposes.
Four wheels installed: 369 HP.
Total steam development: 91 HP.
Total power required: 425 to 450 HP.
Area of mill pond: 20 acres.
Working depth: perhaps 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

189 Rhode Island, Central Falls, Providence County, 1905. (Woonsocket Cases No. 7.)

Farwell Worsted Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 9.787 feet.
10 hour power used.
Character of development: well-developed worsted mill.
Character of watershed: typical New England.
Coal: $4 per 2 000 pounds.
Steam is used for dyeing purposes.
Water is used for dyeing purposes.
Three wheels installed: 169 HP.
Total power: 175 HP.

Power required: 226 HP. plus 75 for electric lights.
Area of pond: 20 acres.
Working depth: 2 feet.

SEE No. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

190 Rhode Island, Central Falls, Providence County, 1905. (Woonsocket Cases No. 8.)

American Hair Cloth Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 9.787 feet.
10 hour power used.
Character of development: well-developed hair-cloth mill.
Character of watershed: typical New England.
Coal: $3.80 per 2 000 pounds.
Steam used for heating and dyeing purposes.
Three wheels installed: 231 HP.
Power required: 100 HP.
Area of pond: 20 acres.
Working depth: 2 feet.

SEE No. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

191 Rhode Island, Central Falls, Providence County, 1895.

City of Worcester *v.* Stafford Manufacturing Company, Central Falls privilege. (Kettle Brook Cases No. 43.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $1 680.

Watershed diverted: 3.856 square miles out of 472.0678 square miles.
Horse-power taken (F. A. McClure, authority):
Petitioner's claim, 8.02.
Defendant's claim, 1.58.
Fall: 10.79 feet.
Character of development: cotton yarns and threads.
Coal: $4.25 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
Water is not used for other purposes than for power.
Four wheels installed: 369 HP.
Total steam and electric power development: 95 HP.
Total power required to run mill: 300 HP.

Approximate area of mill pond: 20 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 135/288 of the flow of the river.

$97.00 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

192 Rhode Island, Central Falls, Providence County, 1895.
City of Worcester *v.* Pawtucket Hair Cloth Company. (Kettle Brook Cases No. 43.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $1 200.

Watershed diverted: 3.856 square miles out of 472.0678 square miles
Horse-power taken (F. A. McClure, authority):
Petitioner's claim, 3.42.
Defendant's claim, 0.78.
Fall: 10.79 feet.
Character of development: hair cloth.
Coal: $3.35 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
Water is used for other purposes than for power.
Three wheels installed: 231 HP.
Total steam and electric power development: 75 HP. electric motor current from Pawtucket Electric Company.
Total power required to run mill: 100 HP.
Approximate area of mill pond: 20 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 60½/288 of the flow of the river.

$97.00 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

193 Rhode Island, Cumberland, Providence County, 1895.
City of Worcester *v.* Manville privileges. (Kettle Brook Cases No. 39.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $7 980.

Watershed diverted: 3.856 square miles out of 426.1515 square miles

Horse-power taken:
Petitioner's claim, 30.55.
Defendant's claim, 6.32.
Fall: 18.818 feet.
Character of development: cotton goods.
Coal: $3.80 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
No water is used for any other purposes than for power.
Six wheels installed, 2 382 HP.
Total steam and electric power development: 2 000 HP.
Total power required to run mill: 2 100 HP.
Approximate area of mill pond: 100 acres.
Approximate depth to which mill pond can be drawn: 1 foot.

$109.80 PER SQUARE MILE PER FOOT OF FALL.

194 Rhode Island, Cumberland, Providence County.

City of Worcester *v.* Lonsdale Company. (*a*) Ashton privilege, (*b*) Lonsdale No. 1, (*c*) Lonsdale No. 4. (Kettle Brook Cases No. 41.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $8 400.

Watershed above privilege: Ashton, 433.0313 square miles.
Lonsdale No. 1, 440.8070 ,, ,,
,, No. 4, 440.8070 ,, ,,
Watershed diverted: 3.856 square miles.
Horse-power taken (authority, F. A. McClure):
Petitioner's claim, 7.90, 9.38, and 11.68.
Defendant's claim, 2.64, 5.39, and 2.61.
Fall: Ashton, 10 feet; Lonsdale No. 1, 25.20 feet; Lonsdale No. 4, 15.20 feet.
Character of development: Ashton, muslin and sheets.
Lonsdale 1, cotton goods.
,, 4, ,, ,,
Coal: $3.80 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
No water used for any other purposes than for power.
Number of wheels installed: Ashton, 4, 375 HP.
Lonsdale No. 1, 2, 410 HP.
,, No. 4, 3, 600 HP.
Total steam and electric power development:
Ashton, 500 HP.
Lonsdale No. 1, 500 HP.
,, No. 4, 950 HP.

Total power required to run mill:
Ashton, 625 to 850 HP.
Lonsdale No. 1, 650 HP.
,, No. 4, 1 250 HP.
Approximate area of mill pond: Ashton, 40 acres.
Lonsdale No. 1, 110 ,,
,, No. 4, 180 ,,
Approximate area to which mill pond can be drawn:
Ashton, 1 foot to 18 inches.
Lonsdale No. 1, 2 feet.
,, No. 4, 1 foot.
Each of these mills is entitled to one half of the flow of the river.
$86.40 PER SQUARE MILE PER FOOT OF FALL.

195 Rhode Island, Cumberland, Providence County, 1895.
City of Worcester *v.* Valley Falls Company, Albion privilege. (Kettle Brook Cases No. 40.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $4 515.

Watershed diverted: 3.856 square miles out of 429.4023 square miles.
Horse-power taken (authority, F. A. McClure):
Petitioner's claim, 21.13.
Defendant's claim, 2.89.
Fall: 13.198 feet.
Character of development: sheetings and shirtings.
Coal: $4 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
Water is not used for any other purposes than for power.
Four wheels installed, 700 HP.
Total steam and electric power development: 600 HP.
Total power required to run mill: 850 HP.
Approximate area of mill pond: 30 acres.
Approximate depth to which mill pond can be drawn: 1 foot.
$88.80 PER SQUARE MILE PER FOOT OF FALL.

196 Rhode Island, Pawtucket, Providence County, 1895.
City of Worcester *v.* Darius L. Goff *et al.*, D. L. & L. B. Goff, Pawtucket privileges. (Kettle Brook Cases No. 45.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $3 096.

Watershed diverted: 3.856 square miles out of 472.5161 square miles.

Fall: 17.021 feet.

Character of development: electricity.

Coal: $3.30 per 2 000 pounds.

Steam sold to D. Goff & Sons.

No water used for any other purposes than for power.

Eleven wheels installed, 1 300 HP. for 5 pairs.

Total steam and electric power development: 520 HP.

Total power required to run mill: 1 300 HP.

Approximate area of mill pond: 1 acre.

Approximate depth to which mill pond can be drawn: None.

This mill is entitled to one half of the remainder of the flow of the river, after deducting 1 400 c.f.m., or about 0.04 of the flow.

$92.45 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

197 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* Charles B. Paine *et al.*, Paine & Taylor privilege on Sargent's trench. (Kettle Brook Cases No. 45.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $105.

Watershed diverted: 3.856 square miles out of 472.5161 square miles.

Horse-power taken: petitioner's claim, 0.48. (F. A. McClure, authority).

Fall: 10.93 feet.

Character of development: power and room rented to small industries.

Coal: $3.30 per 2 000 pounds.

No water is used for any other purposes than for power.

One wheel installed: 40 HP.

Total power required to run mill: 40 HP.

Approximate area of mill pond: 4 acres.

Approximate depth to which mill pond can be drawn: 2 feet.

This mill is entitled to 1 400 c.f.m., or about 0.04 of the flow of the stream.

$92.45 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

198 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* D. Goff & Sons, Lower Dam privilege, east side. (Kettle Brook Cases No. 45.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $2 810.

Watershed diverted: 3.865 square miles out of 472.5161 square miles.

Horse-power taken (authority, F. A. McClure): Petitioner's claim, 26.40; defendant's claim, 7.08.

Fall: 17.021 feet.

Character of development: braids and plushes.

Coal: $3 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than for power.

Two pairs and one single wheel installed, 701 HP.

No steam or electric power development.

Total power required to run mill: 500 HP.

Approximate area of mill pond: 1 acre.

Approximate depth to which mill pond can be drawn: 2 feet.

This mill is entitled to one half of what remains of the flow of the stream after deducting 1 400 c.f.m., or about 0.04 of the flow.

$92.45 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

199 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* Pawtucket Gas Company. (Kettle Brook Cases No. 44.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $367.50.

Watershed diverted: 3.856 square miles out of 472.5161 square miles.

Fall: 7.072 feet.

Horse-power taken (authority, F. A. McClure): Petitioner's claim, 1.70; defendant's claim, 0.39.

Character of development: power and gas.
One wheel installed: power not stated.
Approximate area of mill pond: 4 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 10/64 of the flow of the river.

$82.15 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 5 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

200 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* Littlefield Manufacturing Company. (Kettle Brook Cases No. 44.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $336.

Water shed diverted: 3.856 square miles out of 472.5161 square miles.
Horse-power taken (authority, F. A. McClure): Petitioner's claim, 1.70; defendant's claim, 0.29.
Fall: 8 feet.
Character of development: cotton yarns.
Coal: $3.35 per 2 000 pounds.
Steam is used for manufacturing and other purposes.
No water used for any other purposes than for power.
Three wheels installed, 125 HP.
Total steam and electric power development: 150 HP.
Total power required to run mill: 130 HP.
Approximate area of mill pond: 4 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 10/64 of the flow of the river.

$82.15 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 5 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

201 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* Job L. Spencer, Old Slater privilege. (Kettle Brook Cases No. 44.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $525.

Watershed diverted: 3.856 square miles out of 472.5161 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 2.55; defendant's claim, 0.32.

Fall: 6.50 feet.

Character of development: cotton yarns (mill idle).

Three wheels installed, presumed to be 75 HP.

No steam or electric power development.

Total power required to run mill: 50 to 60 HP.

Approximate area of mill pond: 4 acres.

Approximate depth to which mill pond can be drawn: 2 feet.

This mill is entitled to 15/64 of the flow of the river.

$82.15 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 5 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

202 Rhode Island, Pawtucket, Providence County, 1895.

City of Worcester *v.* Dexter Yarn Company, Pawtucket privilege. (Kettle Brook Cases No. 44.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $525.

Watershed above privilege: 472.5161 square miles.

Water diverted: 3.856 square miles.

Fall: 7.07 feet.

Horse-power taken: Petitioner's claim, 2.70.
Defendant's claim, 0.63.

Character of development: cotton yarns.

Coal: $3.35 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

No water used for other purposes than for power.

Three wheels installed: 150 HP.

Total steam and electric power development: 150 HP.

Total power required to run mill: 267 HP.

Approximate area of mill pond: 4 acres.

Approximate depth to which mill pond can be drawn: 2 feet.

This mill is entitled to 16/64 of the flow of the river.

$82.15 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 5 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

203 Rhode Island, Pawtucket, Providence County, 1895.
City of Worcester *v.* Sylvia C. Pitcher, Pitcher Mill privilege. (Kettle Brook Cases No. 44.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $525.

Watershed diverted: 3.856 square miles out of 472.5161 square miles.
Horse-power taken: Petitioner's claim, 2.22.
Defendant's claim, 0.39.
Fall: 7.07 feet.
Character of development: Power is leased to various tenants.
Coal: $3.35 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
No water is used for any other purposes than for power.
One wheel installed: a little over 50 HP.
Total steam and electric power development: 50 HP.
Total power required to run mill: about 50 HP.
Approximate area of mill pond: 4 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 13/64 of the flow of the river.

$82.15 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 5 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

204 Rhode Island, Pawtucket, Providence County, 1895.
City of Worcester *v.* Fred S. Farwell, Farwell Worsted Company. (Kettle Brook Cases No. 43.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $1 155.

Watershed diverted: 3.856 square miles out of 472.0678 square miles.
Horse-power taken: Petitioner's claim, 5.23.
Defendant's claim, 1.08.
Fall: 10.79 feet.
Character of development: fancy worsteds.
Coal: $3.30 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
Water is used for other purposes than for power.
Three wheels installed: 169 HP.
Total steam and electric power development: 175 HP.

Total power required to run mill: 225 HP.
Approximate area of mill pond: 20 acres.
Approximate depth to which mill pond can be drawn: 2 feet.
This mill is entitled to 92½/288 of the flow of the river.

$97.00 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 3 MILLS ON THIS PRIVILEGE.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

205 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 9.)

S. C. Pitcher Estate *v.* City of Woonsocket.

WELL-DEVELOPED AND SUBSTANTIAL PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 6.572 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: typical New England.
Coal: $3.80 per 2 000 pounds.
Steam is used for heating.
One wheel installed, 50 HP.
Total steam: 50 HP.
Total power required: perhaps 40 HP.
Area of pond: 4 acres.
Working depth of pond: 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARDS NOT KNOWN.

206 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 10.)

Dexter Yarn Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 6.572.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: typical New England.
Coal: $3.50 per 2 000 pounds.
Steam is used for heating purposes.
Three wheels installed: 150 HP.

Steam development: 220 HP.
Total power required: 267 HP.
Area of pond: 4 acres.
Working depth: 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARDS NOT KNOWN.

207 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 11.)

Estate G. L. Spencer *v.* City of Woonsocket.

SUBSTANTIAL AND WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 6.572 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: typical New England.
Three wheels installed, presumed to be 25 HP. each.
Power required: 50 to 60 HP.
Area of pond: 4 acres.
Depth: 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARDS NOT KNOWN.

208 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 12.)

Littlefield Manufacturing Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 6.572 feet.
10 hour power used.
Character of development: well-developed cotton mill.
Character of watershed: typical New England.
Coal: $3.50 per 2 000 pounds.
Steam is used for heating purposes.
Three wheels installed, 125 HP.
Total steam power: 150 HP.
Power required: 130 HP.
Area of pond: 4 acres.
Working depth: 2 feet approximately.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

209 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 13.)

Pawtucket Gas Company *v.* City of Woonsocket.

WELL-DEVELOPED AND SUBSTANTIAL PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 6.572 feet.
Character of watershed: typical New England.
One wheel installed.
Area of pond: 4 acres.
Working depth: 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

210 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 14.)

Pawtucket Electric Company *v.* City of Woonsocket.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 16.521 feet.
24 hour power used.
Character of development: well-developed electric current.
Character of watershed: typical New England.
Coal: $3.35 per 2 000 pounds.
Eleven wheels installed, 1 300 HP.
Total steam development: 520 HP.
Power required: 1 300 HP.
Area of pond: 1 acre.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

211 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 15.)

Taylor & Hallett *v.* City of Woonsocket.

SUBSTANTIAL AND WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 9.93 feet.
10 hour power used.

Character of development: well-developed miscellaneous.
Character of watershed: typical New England.
Coal: $3.35 per 2 000 pounds.
One wheel installed, 40 HP.
Power required: 40 HP.
Area of pond: 4 acres.
Working depth: perhaps 2 feet.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

212 Rhode Island, Pawtucket, Providence County, 1905. (Woonsocket Cases No. 16.)

Pawtucket Electric Light Company.

WELL-DEVELOPED PRIVILEGE, BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

Watershed diverted: 7.9 square miles out of 472 square miles.
Fall: 12.66 feet.
24 hour power used.
Character of development: well developed; electric current.
Character of watershed: typical New England.
Coal: $3.35 per 2 000 pounds.
One wheel installed: 31 HP.

SEE NO. 214, "WOONSOCKET CASES." SEPARATE AWARD NOT KNOWN.

213 Rhode Island, Valley Falls, Providence County, 1895.

City of Worcester *v.* Albion Company, Valley Falls privilege. (Kettle Brook Cases No. 42.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $5 040.

Watershed diverted: 3.856 out of 442.5164 square miles.
Horse-power taken: Petitioner's claim, 23.49; defendant's claim, 4.81.
Fall: 14.609 feet.
Character of development: cotton goods.
Six wheels installed, 1 033 HP.
Total steam and electric power development: 1 200 HP.
Total power required to run mill: 1 000 HP.
Approximate area of mill pond: 50 acres.
Approximate depth to which mill pond can be drawn: 2 feet.

$89.40 PER SQUARE MILE PER FOOT OF FALL.

214 Rhode Island, Woonsocket *et al.*, 1905.
Mill Owners *v.* City of Woonsocket.
WELL-DEVELOPED PRIVILEGES.
Authority: Charles T. Main, Boston.
AGREEMENT (excluding interest), $90 000, divided among the following mill owners. (For detailed statements, see preceding pages):

Name.	Watershed. (Square Miles.) Total.	Watershed. (Square Miles.) Diverted.	Available Fall at Mill. Feet.*	Fall on River. Feet.
1 Valley Falls Co., Albion Mill	429	7.9	12.69	12.69
2 Lonsdale, Ashton	433	7.9	9.50	
3 ,, No. 1	441	7.9	23.28	23.40
4 ,, No. 4	441	7.9	14.03	
5 Albion Co.	443	7.9	14.11	14.11
6 Stafford Co.	472	7.9	9.79	
7 Farwell Worsted Co.	472	7.9	9.79	9.79
8 American Hair Cloth Co.	472	7.9	9.79	
9 S. C. Pitcher Estate	472	7.9	6.57	
10 Dexter Yarn Co.	472	7.9	6.57	
11 Estate G. L. Spencer	472	7.9	6.57	6.57
12 Littlefield Mfg. Co.	472	7.9	6.57	
13 Pawtucket Gas Co.	472	7.9	6.57	
14 Pawtucket Electric Co.	472	7.9	16.52	
15 Taylor & Hallett	472	7.9	9.93	16.52
16 Pawtucket Elec. Lt. Co.	472	7.9	12.66	
Total for 16 mills = $90 000 for		7.9		83.08

$137.00 per Square Mile per Foot of Fall (average for 6 privileges).

215 Rhode Island, Woonsocket, Providence County, 1895.
City of Worcester *v.* George H. Baker. (Leicester Knitting Company privilege, Kettle Brook Cases Nos. 36, 37.)
DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.
Authority: Charles T. Main, Boston.
BY AWARD, $210.

* This column shows the actual fall at mill, but when there are several mills upon the same fall, the water is divided; hence the next column is inserted to give the fall corresponding to the total river flow.

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Horse-power taken: (F. A. McClure, authority): Petitioner's claim, 0.72; defendant's claim, 0.20.

Fall: 7 feet.

Character of development: jackets, mittens, hosiery, etc.

Coal: $3.80 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than for power.

One wheel installed, 135 HP.

Total steam and electric power development: 80 HP. boilers.

Total power required to run mill: 15 to 20 HP.

This mill is entitled to 6/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

216 Rhode Island, Woonsocket, Providence County, 1895.

City of Worcester *v.* American Worsted Company. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $840.

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 3.26; defendant's claim, 0.74.

Fall: 16.667 feet.

Character of development: worsted yarns, braids, etc.

Coal: $3.80 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than power.

Two wheels installed, 125 HP.

Total steam and electric power development: 287 HP.

Total power required to run mill: 300 to 350 HP.

This mill is entitled to 12/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

217 Rhode Island, Woonsocket, Providence County, 1895.

City of Worcester *v.* Eagle Mills. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $1 092.

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 4.26; defendant's claim, 1.00.

Fall: 14.66 feet.

Character of development: cotton goods.

Coal: $3.80 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

Water is used for other purposes than for power.

Two wheels installed, 232 HP.

Total steam and electric power development: 310 HP.

Total power required to run mill: 385 HP.

Approximate area of mill pond: 3 acres.

Approximate depth to which mill pond can be drawn: 1 foot.

This mill is entitled to 18/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

218 Rhode Island, Woonsocket, Providence County, 1895.

City of Worcester *v.* Clinton Manufacturing Company. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $1 680.

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Horse-power taken (F. A. McClure, authority): Petitioner's claim, 7.11; defendant's claim, 1.67.

Fall: 14.66 feet.

Character of development: cotton goods, sheeting, and shirtings.

Coal: $4.90 per 2 000 pounds.

Steam is used for manufacturing or other purposes.

No water used for any other purposes than for power.

Three wheels installed, 310 HP.

Total steam and electric power development: 521 HP.
Total power required to run mill: 500 HP.
Approximate area of mill pond, 3 acres.
Approximate depth to which mill pond can be drawn: 18 inches.
This mill is entitled to 30/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

219 Rhode Island, Woonsocket, Providence County, 1895.
City of Worcester *v.* Frank Harris, Hamlet Mills. (Kettle Brook Cases No. 38.)

DEVELOPED PRIVILEGE ON BLACKSTONE RIVER.

Authority: Charles T. Main, Boston.

BY AWARD, $3 150.

Watershed diverted: 3.856 square miles out of 367.4001 square miles.
Horse-power taken (F. A. McClure, authority): Petitioner's claim, 14.70; defendant's claim, 2.88.
Fall: 9.33 feet.
Character of development: shirtings and sheetings.
Coal: $3.70 per 2 000 pounds.
Steam is used for manufacturing or other purposes.
Water is used for other purposes than for power.
Three wheels installed, 455 HP.
Total steam and electric power development: 125 HP.
Total power required to run mill: about 450 HP.
Approximate area of mill pond: 40 acres.
Approximate depth to which mill pond can be drawn: 2 feet.

$87.70 PER SQUARE MILE PER FOOT OF FALL.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

220 Rhode Island, Woonsocket, Providence County, 1895.
Edgar K. Ray *et al.* (Ray Cotton privilege) *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $420 (exclusive of interest).

Watershed above privilege: 365.2091 square miles.

Horse-power taken (F. A. McClure, authority):
Petitioners' claim, 1.63.
Defendant's claim, 0.37.
Water diverted: 3.856 square miles.
Fall: 16.66 feet.
Character of development: cotton cloth.
Coal: $3.80 per 2 000 pounds.
Steam is used for other purposes.
Two wheels installed, 200 HP.
Total steam and electric power development: 180 HP.
Power required: 200 HP.
Working depth of pond: 18 inches.
This mill is entitled to 6/96 of the flow of the stream.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

221 Rhode Island, Woonsocket, Providence County, 1895.

Woonsocket Electric Machine and Power Company, (*a*) Main Street Station, No. 1 power station privilege, *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $3 717 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.
Horse-power taken (F. A. McClure, authority):
Petitioner's claim, 13.63.
Defendant's claim, 3.20.
Fall: 16.66 feet.
Character of development: power and lighting.
Coal: $3.80 per 2 000 pounds.
Steam is used for other purposes.
Four wheels installed: 600 HP.
Total power: 125 HP.
This mill is entitled to 18/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

222 Rhode Island, Woonsocket, Providence County, 1895.

Woonsocket Electric Machine and Power Company, (*b*) Front Street, No. 2 power station privilege, *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD (included in the preceding).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Fall: 13 feet.

Character of development: electric light and power.

Coal: $3.80 per 2 000 pounds.

Steam is used for other purposes.

Four wheels installed, 410 HP.

Total steam and electric power development: 650 HP.

Area of pond: 14.64 acres.

This mill is entitled to 42/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

223 Rhode Island, Woonsocket, Providence County, 1895.

Social Manufacturing Company (Globe Mill privilege) *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD, $945 (exclusive of interest).

Watershed diverted: 3.856 square miles, out of 365.2091 square miles.

Horse-power taken (F. A. McClure, authority):

Petitioner's claim, 3.90.

Defendant's claim, 1.67.

Fall: 18.333 feet.

Character of development: sheetings.

Coal: $4.80 per 2 000 pounds.

Steam is used for other purposes.

Three wheels installed, 260 HP.

Total power development: 1 100 HP.

Power required: 1 050 to 1 150 HP.

Area of pond: 47.46 acres.

This mill is entitled to 6/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

224 Rhode Island, Woonsocket, Providence County, 1895.

Joseph G. Ray *et al.* (Lyman Mill privilege) *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $446 (exclusive of interest).

Watershed diverted: 3.856 out of 365.2091 square miles.

Horse-power taken (F. A. McClure, authority):

Petitioners' claim, 1.83.

Defendant's claim, 0.47.

Fall: 18.333 feet.

Character of development: cotton cloth mill.

Coal: $4.00 per 2 000 pounds.

One wheel installed, 100 HP.

Power required to run mill: 35 HP.

Working depth of pond: 1½ feet.

This mill is entitled to 6/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

225 Rhode Island, Woonsocket, Providence County, 1895.

Edgar K. Ray *et al.* (*a*) Bartlett privilege, (*b*) Ballou privilege, *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston.

BY AWARD $1 648 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Horse-power taken: (F. A. McClure, authority):

Petitioners' claim, Bartlett, 1.56; Ballou, ?

Defendant's claim, Bartlett, 1.32; Ballou, ?

Fall: 18.333 feet.

Character of development:

Ballou, cotton spinning.

Bartlett, cotton weaving and spinning.

Coal: about $4 per 2 000 pounds.

Steam is used for other purposes.

Wheels installed: Ballou, two 300 HP.
Bartlett, one 70 HP.
Total power development: Ballou, 275 HP.
Bartlett, 50 HP.
Power required: Ballou, 300 HP. (about).
Bartlett, 75 HP.
Ballou mill is entitled to 17/96 of flow of river.
Bartlett mill is entitled to 6/96 of flow of river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

226 Rhode Island, Woonsocket, Providence County, 1895.

Margaret F. O'Reilly *et al.* (grist mill privilege) *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED WATER PRIVILEGE.

BY AWARD, $268.50 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.
Horse-power taken (F. A. McClure, authority): Petitioners' claim, 1.85; defendant's claim, 0.53.
Fall: 18.333 feet.
Character of development: meal mill.
Three wheels: 122 HP.
This mill is entitled to 3/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

227 Rhode Island, Woonsocket, Providence County, 1895.

Margaret F. O'Reilly *et al.* (Harris Woolen Company privilege) *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED PRIVILEGE.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $268.50 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.
Fall: 18.333 feet.
This mill is entitled to 3/96 of the flow of the river.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

228 Rhode Island, Woonsocket, Providence County, 1895.

Lippitt Woolen Company *v.* City of Worcester. (Kettle Brook Cases Nos. 36, 37.)

DEVELOPED WATER PRIVILEGE.

Authority: Charles T. Main, Boston, Mass.

BY AWARD, $1 050 (exclusive of interest).

Watershed diverted: 3.856 square miles out of 365.2091 square miles.

Fall: 16.66 feet.

7.33 ,,

Character of development: woolens.

Coal: $3.80 per 2 000 pounds.

Steam is used for other purposes.

Water is used for other purposes.

Two 100-HP. wheels installed.

Total electric and steam power development: 200 HP.

Power required: 220 HP.

Working depth of pond: 1 foot to 18 inches.

This mill is entitled to 12/96 of the flow of the river on the 16.66 foot fall, and 6/96 on the 7.33 foot fall.

$103.95 PER SQUARE MILE PER FOOT OF FALL = TOTAL FOR 13 MILLS ON 2 PRIVILEGES.

SEE NO. 129, "MASSACHUSETTS, WORCESTER, SUMMARY OF KETTLE BROOK CASES."

229 Vermont, Barre, Washington County, 1897.

Barre Water Company *v.* MacFarland & Boyce.

SMALL DEVELOPED PRIVILEGE.

Authority: C. T. Main, Boston, Mass.

AWARD, $300 (exclusive of interest).

Character of privilege: variable, small flow in dry months.

Watershed above privilege: 42 square miles.

Watershed taken: 2.7 square miles.

Fall taken and developed: 8 feet.

9 hour working day.

Character of development: stone cutters.

Watershed: hilly.

Coal per 2 000 pounds: $4.02.

One 15 HP. wheel installed.

Power required to run mill: 15 HP.

Area of mill pond: very small.

Storage reservoirs: Peck pond, 20 acres, 12 feet deep = 20 454 400 cubic feet.

$13.90 PER SQUARE MILE PER FOOT OF FALL.

230 Vermont, Barre, Washington County, 1897.
Barre Water Company *v.* The Woolen Mill.
DEVELOPED PRIVILEGE. UNUSED.
Authority: C. T. Main, Boston, Mass.
AWARD, $900 (exclusive of interest).

Character of privilege: variable, small flow in dry months.
Area of watershed: 42 square miles.
Watershed taken: 2.7 square miles.
Fall: 28 feet 4 inches.
Fall used: 28 feet 4 inches.
No wheel, steam power, or business; abandoned about 5 years.
Character of watershed: hilly.
Coal per 2 000 pounds: $4.02.
Area of mill pond: small.
Storage reservoirs: Peck pond, 20 acres, 12 feet deep = 20 454 400 cubic feet.

$11.80 PER SQUARE MILE PER FOOT OF FALL.

231 Vermont, Barre, Washington County, 1897.
Barre Water Company *v.* McDonald & Buchan.
SMALL DEVELOPED PRIVILEGE.
Authority: C. T. Main, Boston, Mass.
AWARD, $1 350 (exclusive of interest).

Character of privilege: variable, small flow in dry months.
Watershed above privilege: 42 square miles.
Watershed taken: 2.7 square miles.
Fall taken and developed: 12 feet 3 inches.
9-hour power used.
Character of development: stone cutters.
Character of watershed: hilly.
Coal: 2 000 pounds, $4.02.
One 30-inch Hercules wheel 57 HP. installed.
Boiler: 25 to 30 HP. engine.
Power required: 57 HP.
Supplementary steam necessary: about 23 HP. average for seven months.
Area of mill pond: small.
Storage reservoirs: Peck pond, 20 acres, 12 feet deep = 20 454 400 cubic feet.
Controlling factor in award: simply to make good the value of power diverted.

$40.80 PER SQUARE MILE PER FOOT OF FALL.

232 Vermont, Barre, Washington County, 1897.
Barre Water Company *v.* Marr & Gordon.
DEVELOPED WATER PRIVILEGE.
Authority: Charles T. Main, Boston, Mass.
BY AWARD, $1 100 (exclusive of interest).

Character of privilege: variable, small flow in dry months.
Area of watershed: 42 square miles.
Watershed taken: 2.7 square miles.
Fall taken and developed: 14 feet 8 inches.
9 hour power used.
Character of development: stone dam.
Character of watershed: hilly.
Cost of coal per 2 000 pounds: $4.02.
Steam is used for other purposes.
One 30-inch Hercules wheel installed, 78 HP.
Total steam development: 100 HP. boiler, 45-40 HP. engine.
Power required to run mill: 40 HP.
Supplementary steam necessary: about 24 HP. average for six months.
Area of mill pond: 50 feet by ½ mile.
Storage reservoirs upon watershed: Peck's pond, 20 acres, 12 feet deep = 20 454 400 cubic feet.
Controlling factor in award: to make good power diverted.

$27.70 PER SQUARE MILE PER FOOT OF FALL.

233 Vermont, Barre, Washington County, 1897.
Barre Water Company *v.* J. S. Robinson.
SMALL DEVELOPED PRIVILEGE.
Authority: C. T. Main, Boston, Mass.
AWARD, $1 100 (exclusive of interest).

Character of privilege: variable small flow in dry months.
Area of watershed: 42 square miles.
Watershed diverted: 2.7 square miles.
Fall: 22 feet 7 inches.
Fall used: 22.58 feet.
9 hour working day.
Character of development: wooden dam, in very poor repair.
Watershed: hilly.
Coal: $4.02 per 2 000 pounds.
One wheel 120 HP. installed.
Power required to run mill: 60 HP.
Area of mill pond: 100 feet wide.
Storage reservoirs upon watershed:
20 acres, 12 feet deep = 20 454 400 cubic feet.

$18.00 PER SQUARE MILE PER FOOT OF FALL.

APPENDIX C.

December 7, 1908.

NEW ENGLAND WATER WORKS ASSOCIATION.

Data for Committee upon Water and Water-Power Diversion.

Kindly fill in and return this data sheet to LEONARD METCALF,
Secretary Water and Water-Power Diversion Committee,
14 Beacon Street, Boston, Mass.

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1. Date of valuation, sale, or award.
2. Amount thereof, exclusive of interest ($).
3. Total amount, including interest and allowances for collateral items.
4. Corporate names of both parties.
5. Location, town, city, county, and state.
6. Character of privilege.
7. Total area of watershed above privilege.
8. Amount of watershed taken or diverted.
9. Amount of water taken or diverted.
10. Theoretical fall taken to which right was claimed.
11. Fall used or developed.
12. Hours per day during which power is used.
13. Character of development, product of mill, etc.
14. Character of watershed.
15. Cost of coal per 2 000 pounds, and of electric current per kilowatt hour.
16. Is steam used for manufacturing or other purposes?
17. Is water used for any other purposes than for power?
18. Number of wheels installed.
19. Power of wheels.
20. Total steam and electric power development.
21. Total power required to run mill.
22. If supplementary steam or electricity is necessary, state amount.
23. What must be done to improve the privilege, or to develop undeveloped available power there, and what is the estimated cost thereof?
24. Approximate area of mill pond.
25. Approximate depth to which mill pond can be drawn.
26. Are there storage reservoirs upon the watershed? If so, state capacity.
27. Character of control of the storage.
28. What were the controlling factors in the award?
29. Did the award include any allowances other than for the water or water power?

Remarks:

(Signed)

APPENDIX D.

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Compensation in Kind for Diversion of Water. By Robert E. Horton. (Vol. 22, p. 334, September, 1908.)

Power of a Running Stream without Storage. By William G. Raymond. (Vol. 22, p. 184, June, 1908.)

The Newton, N. J., Water Works, etc. By L. L. Tribus. (Vol. 23, June, 1909.)

PAPERS IN TRANSACTIONS OF AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Comparative Cost of Steam and Water Power. By Charles H. Manning. (No. 332, Vol. X, p. 499.

Cost of Steam and Water Power. By Charles T. Main. (No. 360, Vol. XI, p. 108.)

Value of a Water Power. By Charles T. Main. (No. 471, Vol. XIII, p. 140, 1892.)

Cost of an Indicated Horse Power. By DeCourcy May. (No. 603, Vol. XV, p. 1146.)

On the Value of a Horse Power. By George I. Rockwood. (No. 848, Vol. XXI, p. 590.)

An Analysis of the Commercial Value of Water Power per Horse Power per Annum. By A. F. Nagle. (No. 967, Vol. XXIV, p. 286.)

Computations of the Values of Water Powers and the Damages Caused by the Diversion of Water Used for Power. By Charles T. Main. (No. 1057, Vol. XXVI.)

LIBRARY OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

SEARCH FOR MATERIAL ON AWARDS FOR WATER OR WATER-POWER DIVERSION, MARCH 11, 1909.

NOTE. — Theoretical articles are omitted. This is not a complete search.

These references result from an examination of the following: Transactions American Society of Civil Engineers; Catalogue of the library, under "Water Supply Works" from Adams, Mass., to Fall River, Mass.; Engineering Index, 1881 to 1907, inclusive; Journal of the Franklin Institute, 1826 to 1885, inclusive; "Bibliography of Municipal Problems and City Conditions," by Robert C. Brooks; Engineering News, 1872 to 1904, inclusive.

Calculations of the Mean Horse-Power of a Variable Stream and the Cost of Replacing the Power Lost by a Partial Diversion of the Flow. By William H. Grant, member American Society of Civil Engineers. Transactions American Society of Civil Engineers, Vol. 22, p. 402 (Paper 440, June, 1890). (A brief reference in the discussion by Charles E. Emery, member American Society of Civil Engineers, to damages awarded by the city of Fall River, Mass., for the use of part of the water from Watuppa Ponds.)

Water Power at Niagara Falls. By Samuel McElroy. Journal Association of Engineering Societies, Vol. 4, p. 395, September, 1885. (Award for land, including hydraulic power taken by New York legislature to locate a public park. State award, $81 690 for the entire claim, of which it is said the allowance for water power was based on 105 HP. at $10.)

A Retrospect of an Arbitration on the Value of a Water Works. By Albert H. Wehr. Proceedings. American Water Works Association, Vol. 26, p. 361, 1906. John M. Diven, Secretary, Charleston, S. C. (In an arbitrated case of the mayor and city council of Baltimore against the Baltimore County Water and Electric Company, the award was fixed at $230 618. This amount equaled a capitalization, at 4 per cent., of the loss of the present net income.)

Compensating Reservoirs for Gravity Water Supplies in Lieu of Compensation for Riparian Rights and Its Legal Aspects. By S. E. Babcock. Proceedings American Water Works Association, Vol. 18, p. 101, 1898. John M. Diven, Secretary, Charleston, S. C. (The city of Little Falls pays $5 000 for right to the diversion of water.)

Abstract of same. *Compensation Water for Mills.* Engineering Record, Vol. 38, p. 76, June 25, 1898.

A Method of Estimating the Loss of Water Power in a Stream by Taking the Water therefrom for a City Supply. By L. M. Hastings. Journal New England Water Works Association, Vol. 7, p. 187, June, 1893. (The owners of four water powers on Charles River, below its junction with Stony Brook, brought suit against the city of Cambridge for compensation for diversion of water. Instead of a damage of $160 000 as claimed, the commissioners awarded the lump sum of $15 000.)

Abstract of same. *Estimation of the Loss of Water Power in a Stream by Taking Water for a City Supply.* Engineering Record, Vol. 27, p. 296, March 11, 1893.

An Important Decision upon a Mill Owner's Suit to Collect Damages for Diversion of Water (letter). By Louis L. Tribus. Engineering News, Vol. 43, p. 228, April 5, 1900. (The Sparks Manufacturing Company and W. H. Ingersoll brought suit for diversion of water against the town of Newton, N. J.; the awards in the lower court were $3 302 and $2 650, being on the old principle of equivalent cost of steam power capitalized. The Court of Appeals and Errors reversed the award, making it on the basis of difference in market value before and after diversion; therefore states that $750 and $500 respectively to Sparks and Ingersoll is ample remuneration.)

The Ownership of Underground Water in New York (editorial). Engineering Record, Vol. 39, p. 447, April 15, 1899. (In a suit of Forbell *v.* City of New York, $6 000 damages were awarded for the diversion of underground water.)

The Estimation of Damages to Power Plants from Back Water. Engineering Record, Vol. 45, p. 392, April 26, 1902. (A decision of the Maine Supreme Court in National Fiber Board Company *v.* Lewiston & Auburn Electric Light Company; plaintiff was awarded $800.)

A New Ruling Concerning Underground Water Rights. Engineering Record, Vol. 44, p. 49, July 20, 1901. (Award of damages to market gardeners for pumping underground water by New York City.)

Proposed Compensation in Kind for Water Diverted for the Supply of Norwich, Conn. By Hill, Quick, and Allen. Engineering News, Vol. 45, p. 381, May 23, 1901.

The Latest Decision Affecting Underground Water Supplies, Borough of Brooklyn, New York City. Engineering News, Vol. 44, p. 385, December 6, 1900. (Forbell *v.* City of New York. Award, $6 000.)

Water Power, Its Measurement and Value, with Data Respecting Damages Awarded. By George A. Kimball. Journal Association of Engineering Societies, Vol. 13, p. 71, February, 1894. Damages awarded to Willard Sibley and others caused by the taking of land, water power, and mills in the city of Waltham and town of Weston, Mass. The award of the commission, including all damages for taking land, buildings, water power, and machinery, was $34 023 and interest. The city paid in settlement $35 543, with interests and costs. The water power was estimated at $10 000 by the commissioners. Pages 84 and 104 give a number of other awards for water diversion.)

The Schuylkill Navigation Company's Canal and Water Rights. Engineering News, Vol. 24, p. 492. November 29, 1890 (Awards by the city of Philadelphia to several counties for the water rights in the canal as a means for increasing the water supply of Philadelphia.)

Discussion on Diversion of Water Power. Journal New England Water Works Association, Vol. 21, p. 272, September, 1907. (Contains a table showing awards made in

1903 for damage to water powers below dam of Tomhannock Reservoir, Troy, N. Y., water works.)

On the Value of a Horse-Power. By George I. Rockwood. Transactions American Society of Mechanical Engineers, Vol. 21, p. 590, 1900. (The award for the diversion of Kettle Brook by the city of Worcester was $615 259.)

The Value of a Water Power. By Charles T. Main. Transactions American Society Mechanical Engineers, Vol. 13, p. 155, 1891–92. (Brief reference in discussion to damages awarded by the city of Fall River, Mass.)

Holyoke Water Power Company v. City of Holyoke. Vol. 20, p. 119. Boston, 1903. George H. Ellis, 272 Congress Street. (Awards for diversion of water.) (Ia-28.)

In Supreme Court, General Term, Fifth Department. In the Matter of the Application of the City of Rochester to Acquire the Permanent and Perpetual Right to Draw from Hemlock and Canadice Lakes an Amount of Water Sufficient for the Use of Said City and Its Inhabitants not Exceeding Nine Millions of Gallons per Day. Record on Appeal from Order Confirming Report of Commissioners, Vol. 1, p. 79, 1884. (Original awards for water diversion.) (Dc-472.)

Annual Report of the Syracuse Water Board of the City of Syracuse, N. Y., Year Ending July 31, 1894, p. 21. Syracuse, 1894. John T. Delany. Superintendent Bureau of Water. (The awards in condemnation cases to acquire eighteen different water-power rights upon the outlet of Skaneateles Lake.)

First Annual Report of the Metropolitan Water and Sewerage Board, January 1, 1902, p. 20. Boston, 1902. Henry H. Sprague, chairman, 1 Ashburton Place. (Award to the city of Boston for entire damages for taking, on January 1, 1898, of the sources of water supply and other property of that city, fixed at $12 531 000.) (Dc-1112.)

Sixth Annual Report of the Metropolitan Water Board, January 1, 1901, p. 34. Boston, 1901. (Settlement effected with the city of Nashua for the taking and diversion of the waters of the south branch of the Nashua River. Award, $33 000.) (Dc-505.)

Library of the American Society of Civil Engineers.

SEARCH FOR MATERIAL ON AWARDS FOR WATER OR WATER-POWER DIVERSION, MARCH 24, 1909.

Note. — Continuation of search on the same subject made March 11, 1909.

These references result from an examination of the following: Catalogue of the library under " Water Power " ; also under " Water Supply Works " from Fall River, Mass., to Lyons, France, inclusive.

Report of the Water Commissioners, Fitchburg, Mass., 1892, pp. 15, 22. Fitchburg, Mass, 1893. Thomas C Lovell, clerk Board of Water Commissioners. (Awards were made to Franklin Wyman, land, water rights, buildings, and machinery, $75 000; and to parks, land, and water rights, $1 800.) (Dc-55.)

Second Annual Report of the Water Commissioners of the City of Fitchburg, pp. 15–19. Fitchburg, Mass., 1874. (Award for land damages and water right, $2 400 made at Warren W. Shattuck for the diversion of Shattuck Brook.)

Third Report of the Water Commissioners of the Town of Fitchburg, ending January 6, 1873, pp. 6–8. (Settled with James P. Putnam for $2 000 and with William Baker for $1 500 for diverting water from their mill privileges.)

Third Annual Report of the Board of Water Commissioners of the Village of Gloversville, N. Y., for the Year Ending April 30, 1880, p. 24. Gloversville, N. Y. Alexander Orr, clerk, Board of Water Commissioners. (Award for damages to A. J. Kasson, Morris mill, $3 250. Arbitration, $45.) (Dc-57.)

Sixth Annual Report of the Water Commissioners of Gloversville, N. Y., February 1, 1896, pp. 15–27. (Claims allowed for damages by water commissioners.)

Seventh Annual Report of the Water Commissioners of Gloversville, N. Y., February 1, 1897, p. 7. (Award to Edward Elphee for diversion of the Potter and Rice Creeks was $506.41.)

Ninth Annual Report of the Board of Water Commissioners of the City of Gloversville, N. Y., February 1, 1899, p. 9. (Judgments paid with costs during the year.)

City of Bangor, 1878–89, Annual Report of the Water Board, pp. 10–13. Bangor, Me., 1879. (The whole amount paid for flowage thus far, including $846.15 paid last year, is $3 282.75 damages, and $341.57 costs.) (Dc-422.)

The Water Question, a Plain Statement of the Case in All Its Bearings, with the Accompanying Documents and Map, April, 1877, pp 34–57. By Edward Saportas, New York, 1877. Amerman & Co., 47 Cedar Street. (Paid to the Mahopac Manufacturing Company for balance due for water drawn from Lake Mahopac and Lake Kirk during summer and fall of 1870, $10 500; also refers in the preface to an award for damages of 6½ cents for tapping Lake Mahopac.) (Dc-1367.)

Report of the Selectmen on the Financial Affairs of the Town of Hingham for the Year Ending February 1, 1876, p. 142. Hingham, 1876. ($3 000 was paid for mill property and privilege at Accord Pond.) (Oh-35-2.1.)

Reports on a Municipal Water Supply for the City of Gloucester, Mass., April 7, 1894, and March 5, 1895, p. 10. Gloucester, Mass., 1895. (An old mill privilege, for which $2 000 was paid: and Dike's meadow flowage area, for which something less then $2 000 was paid, etc., were brought from various owners.) (Dc-1339.)

Report of the Board of Water Commissioners, Franklin, N. H., 1892, pp. 18–47; 1893, p. 12. Franklin Falls, N. H., 1892–93. (Refers to purchase of water power from the Winnepissiogee Paper Company and W. F. Daniell.) (Dc-1131.)

LIBRARY OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

SEARCH FOR MATERIAL ON AWARDS FOR WATER-POWER DIVERSION, APRIL 20, 1909.

NOTE. — This is a continuation of searches on the same subject made March 11 and 24, 1909.

These references result from an examination of the following: Catalogue of the library under "Water Supply Works," from Paris, France, to Zurich, Switzerland. Engineering Index, 1908.

The Twenty-Ninth Annual Report of the Board of Water Commissioners of the City of Hartford for the Year Ending March 1, 1883, p. 10. Hartford, Conn., 1883. Fred T. Berry, Secretary. (The law suit brought by Martin Luther, of Newington, against the Board of Water Commissioners, for diverting water from his mill privilege by the construction of Farmington reservoir, has ended in a verdict in his favor for $2 750, which, with cost of proceedings, brings the loss to over $3 500.) (Dc-59.)

Annual Report of the Board of Water Commissioners of the City of Holyoke, December 28, 1874, p. 9. Holyoke, Mass., 1875. Thomas J. Carmody, Secretary. (In the suit of J. S. Hurlbutt and others to recover damages for the taking of the waters of Ashley's and Wright's ponds, the jury returned a verdict in the alternative, assessing the damages at $2 000 if the claimants are entitled only to the natural flow of the brook running from the lower pond, and at $4 000 if they also have a right to raise the waters in the ponds by a dam, and use them as reservoirs, the claimants' rights to be determined by the Supreme Court hereafter.) (Dc-61.)

Annual Report of the Board of Water Commissioners of the City of Holyoke, December 31, 1875, p. 13. Holyoke, Mass., 1896. (A settlement of the Hurlbutt suit was made by the payment of the verdict and costs without interest. It was thought that the Supreme Court would overrule the claim on which the lesser verdict was based, and that if a new trial was had, the damages awarded were as likely to be more as less, and that it was advisable, under the circumstances, to stop costs and interest by a settlement. The amount of $4 317.71 was, therefore, paid to the plaintiff's attorneys, and a full discharge of this vexatious claim obtained.) (Dc-61.)

Annual Report of the Water Board of the City of Holyoke, 1882, p. 7. Holyoke, Mass, 1883. (In order to make fully available and also to keep from pollution the waters of Tannery Brook, we have purchased of Austin Goodyear the tract of land known as the "Bagg" farm, together with the buildings situated thereon; also the right and privilege to forever divert the waters of Tannery Brook, paying therefor the sum of $3 300, which is full payment for any damage that said Goodyear may sustain by reason of said diversion.) (Dc-61.)

Thirty-First Annual Report of the Water Board of Holyoke, Mass., for the Year 1902, p. 7. Holyoke, Mass., 1903. (The Shoals damage case, one of the cases in connection with the taking of the southwest branch of the Manhan River, was settled for $676.94.)

Third Annual Report of the Leominster Water Board, Year Ending March 1, 1875, p. 10. Leominster, Mass. W. J. Wetherbee, Superintendent. (Awards for damages caused by the diversion of Morse Brook, the "Woolen Mill," or "Crocker" privilege, $1 666.67: the privilege belonging to the Messrs. Lockey Brothers, $1 100. Twelve other cases have been settled in which the parties have been paid $16 075, names of the parties not mentioned. In treasurer's report payments to six different firms or persons for water rights and land are noted.) (Dc-74.)

Reports of the Water Commissioners and Water Registrar of Malden, Mass., for 1875, p. 3. Boston, Mass, 1876. George W. Barrett, Water Registrar. (A verdict has been rendered in favor of James P. Thorndike, for damages to the Hurd and Grundy Mills for $1 000, with costs and interest, amounting to $1 825. The claim of the Haywardville Rubber Company has been settled by the payment of the $10 000 and costs and interest amounting to $14 679.92.) (Dc-81.)

Fourth Annual Report of the Water Commissioners of the Town of Medford, 1874, p. 3. Medford, Mass. Frederick W. Gow, Superintendent. (The suits for water damages of Henry Barrett *et al.* and of George W. Phillips, administrator of estate of David Dyer, have been tried before the sheriff's jury, and in a former case a verdict of $11 500 with interest was returned, and in the latter case $50 397.78, interest included.) (Dc-87.)

Annual Report of the Water Commissioners of the Town of Medford, 1875, p. 5. Medford, Mass., 1875. (Further data on the above awards.) (Dc-81.)

Report of the Water Commissioners of the Town of Medford for the Year 1875, p. 5. Medford, Mass., 1876. (Awards to the Haywardville Rubber Company and John P. Thorndike for damages arising from taking the water.) (Dc-87.)

Report of the Water Commissioners of the Town of Melrose for the Year Ending January 1, 1874, p. 53. Melrose, Mass. (Claims for damages for diversion of water made conjointly against the three towns, Melrose, Medford, and Malden.) (Dc-88.)

Report of the Board of Water Commissioners of the Town of Melrose for Year Ending January 1, 1875, Boston, 1875. (Awards for the above claims for damages.) (Dc-88.)

Report of the Board of Water Commissioners of the Town of Melrose for the Year Ending March 1, 1876, p. 3. Boston, 1876. (Dc-88.)

City of Meriden, Annual Report of the Water Department, Year Ending November 30, 1884, p. 6. Meriden, Conn. (Award for diversion of water to the Peck, Stow & Wilcox Co., of Southington and Berlin, $5 500.) (Dc-90.)

City of Meriden, Annual Report of the Water Department, Year Ending November 30, 1885, p. 5. (Award to the Moore Manufacturing Company, $500, and the Dudley Mills, $225, for diversion of water.) (Dc-90.)

Annual Report of the Board of Water Commissioners of the City of New Britain, Conn., for the Year Ending March 31, 1900, pp. 4–13. New Britain, Conn. P. J. Egan, clerk. (Awards for mill damages by the diversion of water.) (Dc-97.)

Forty-Eighth Annual Report of the Board of Water Commissioners of the City of New Britain, Conn., for the Year Ending March 31, 1905, p. 14. New Britain, Conn., 1905. (Award to D. E. Mills for land, buildings, and water rights, $4 600.) (Dc-97.)

City of Newton, Mass., Annual Report of the Water Commissioner for the Year Ending December 31, 1903, p. 3. Newton, Mass. J. C. Whitney, water commissioner. (A payment of $15 000 was made to the owners of mill privileges on the Charles River for the right to take 3 500 000 gallons daily in addition to the 1 500 000 for which the city made a settlement in 1879.) (Dc-305a.)

Report of the Superintendent of the City of Norwich Water Works to the Board of Water Commissioners from April 1, 1877, to March 31, 1878, p. 3. Norwich, Conn. (States that all of unsettled claims against the Board of Water Commissioners for damages for turning the water of "Byron Brook" have been settled, including suits in court of E. R. Cory, $1 500 award, and C. C. Bliss, $400.) (Dc-114.)

Twenty-Second Annual Report of the Executive Board of the City of Rochester, N. Y., for the Year Ending December 31, 1897, p. 59. Rochester, N. Y. Edwin A. Fisher, city engi-

neer. (The heirs of Cora J. Trimmer were awarded $1 000 as a settlement for claims for damages of mill privilege on Honeoye Lake by the diversion of water from Canadice and Hemlock lakes.) (Or 15-2.1.)

Nineteenth and Twentieth Annual Reports of the Executive Board of the City of Rochester for the Years from April 1, 1894, to January 1, 1896, p. 65. (Awards for diversion of water from Honeoye Creek and from Hemlock and Canadice lakes.) (Or 15-2.1.)

Seventeenth Annual Report of the Executive Board, Rochester, N .Y., 1893, p. 18. (Damages paid to owners for damages to mill privilege.) (Or 15-2.1.)

Sixteenth Annual Report of the Executive Board, Rochester, N. Y., 1892, p. 69. (List of the owners of mill privileges on Honeoye Creek, Hemlock outlet, and Canadice outlet, in relation to the matter of obtaining options on the damages to the various mill privileges.) (Or 15-2.1.)

Fifteenth Annual Report of the Executive Board of the City of Rochester, N. Y., for the Year Ending April 5, 1891, p. 82. (List of owners of mill privileges from whom options have been secured.) (Or 15-2.1.)

Tenth Annual Report of the Executive Board of the City of Rochester, N. Y., for the Year Ending April 5, 1886, p. 90. (Awards made for damages to mill powers on Hemlock Lake outlet and Honeoye Creek.) (Or 15-2.1.)

Eighth Annual Report of the Executive Board of the City of Rochester for the Year Ending April 7, 1884, p. 28. (Or 15-2.1.)

Twenty-Third Annual Report of the Executive Board of the City of Rochester, N. Y., for the Year 1898, p. 53. (Or 15-2.1.)

First Annual Report of the Department of Public Works of the City of Rochester for the Year 1900, p. 134. (Or 15-3.1.)

Town of Reading, Twelfth Annual Report of the Water Commissioners for the Year 1902, pp. 15–16. Reading, Mass. Lewis M. Bancroft, superintendent. (Award for damages to the Ipswich Mills, $10 495.77.) (Dc-1310.)

Town of Reading, the Sixteenth Annual Report of the Water Commissioners for the Year 1905, pp. 14–15. (Settlement of the claims of the Norwood and Middleton mills for water diversion was made for $1 102.05 and $4 988.33.) (Dc-1310.)

Fifth Quarterly Report of the Water Commissioners of the City of Providence, January 2, 1871, p. 8. Providence, R. I. The City Engineer. (Purchase of the American Wood Paper Company at Pawtuxet for $50 000 disposes of all known claims for damages in consequence of the proposed diversion of the waters of the Pawtuxet River.) (Dc-136.)

The Third Annual Report of the Water Commissioners of the City of Poughkeepsie for the Year Ending February 1, 1872, p. 10. Poughkeepsie, N. Y. (Awards fixed by a commission of the Supreme Court were, to Messrs. Pelton, $40 000; Charles Swift, $6 000; John G. Parker, $16 000, etc. The awards were accepted with the exception of that to the Messrs. Pelton; after some delay an arrangement was effected with Messrs. Pelton and the mill owners below.) (Dc-132.)

City of Salem, Twenty-Eighth Annual Report of the Salem Water Board to the City Council, December, 1896, p. 8. Salem, Mass. David N. Cook, superintendent. (The claims against the city of Salem from the Ipswich Mills or damages sustained have been settled by the payment of $10 000.) (Dc-513.)

Annual Report of the Syracuse Water Board of the City of Syracuse, N. Y., Year Ending July 31, 1894, p. 21. Syracuse, N. Y. John T. Blaney, superintendent. (Awards in the condemnation cases to acquire eighteen different water power rights upon the outlet of Skaneateles Lake.) (Dc-353.)

Ninth Annual Report of the Syracuse Water Board to the Mayor and Common Council of the City of Syracuse for the Year Ending June 30, 1898, p. 24. (Condemnation of water power rights connected with mill properties upon the outlet of Skaneateles Lake.) (Dc-353.)

Twenty-Second Annual Report of the Water Commissioners of the City of Taunton, Mass., November 30, 1897, p. 21. Taunton, Mass. Henry M. Lovering, commissioner. (The claim of Nemasket Mills for interference with the natural flow of the Nemasket River was settled for $500.) (Dc-158.)

City of Springfield, Twenty-Ninth Annual Report of the Board of Water Commissioners for the

Year 1902, p. 10. Springfield, Mass. Everett E. Stone, chairman. (A settlement of claim of mill owners on the Chicopee River for damages growing out of the diversion of the waters of Jabish Brook in June, 1891, was made during 1902; the aggregate sum of $73 000 was paid.) (Dc-406.)

City of Springfield, Twenty-Sixth Annual Report of the Board of Water Commissioners for the Year 1899, p. 12. (Several claims for land damages caused by diverting the waters of Jabish Brook were settled during 1899 in accordance with jury awards before the Hampshire County Superior Court.) (Dc-406.)

City of Springfield, Twenty-Fourth Annual Report of the Board of Water Commissioners for the Year 1897, p. 8. (Claim for damage by the diversion of Jabish Brook was settled by the award of $3 800 to the Nathan W. Bond estate.) (Dc-406.)

Third Annual Report of the Board of Water Commissioners of the City of Waterbury, p. 6, 1870. Waterbury, Conn. The Secretary. (Several corporations and owners of property on Mad River claimed damages for the taking of water from East Mountain Brook.) (Dc-237.)

Twenty-Ninth Report of the Board of Water Commissioners of the City of Waterbury for the Year 1895, p. 37. (Awards to several manufacturing companies on the Mad River for taking the waters of " Turkey Hill " Brook by the Board of Water Commissioners.) (Dc-237.)

Worcester Water Works, Reports of the Committee on Construction and of the Aqueduct Commissioner for the Year 1864, p. 12. Worcester, Mass. City Engineer. (Expenditure for water rights of seven mill owners was $2 350.) (Dc-431, p. 193.)

Thirty-Fifth Annual Report, Chief Engineer of the Water Department to the Board of Water Commissioners, Wilmington, Del., for the Year 1904, pp. 8, 155, 242. Wilmington, Del. Theodore A. Leisen, chief engineer. (Itemized finding of the Arbitration Commission and full details of the valuation of water power in claims for damages by E. I. DuPont Company, Jos. Bancroft & Sons Co., and Jessup & Moore Paper Co., for the diversion of water.) (Dc-169.)

Annual Report of the Chief Engineer of the Water Department to the City of Wilmington for the Year 1883, p. 5. (The legislature of 1883 passed an act authorizing the purchase, at a cost of $60 000, of all the water rights of " South Long Race.") (Dc-169.)

Report of the Cochituate Water Board to the City Council of Boston for the Year Ending April 30, 1876, p. 7. Boston, Mass. (On December 30, 1875, a settlement was made with the Wameset Power Company, of Lowell, for damages in full by the taking of the water of Sudbury River for the sum of $55 000.) (Dc-489.)

Second Annual Report of the Boston Water Board for the Year Ending April 30, 1878, p. 12. Boston, Mass. (Awards for damages by the taking and diversion of the waters of the Sudbury River to the Saxonville Mills, $175 000, and interest from December, 1876; the Belvidere Woolen Manufacturing Company, $40 000; Charles P. Talbot *et al.*, $76 500; Marshall P. Wilder *et al.*, $16 500.) (Dc-490.)

Final Report of the Water Commissioners of the City of Lawrence to the City Council, p. 87. Lawrence, Mass., 1876. (For the sum of $15 000 the Essex Company abandoned all claims against the city on account of raising the water in the river and relinquished to the city the use of its lands.) (Dc-373.)

Search Made in the Library of the American Society of Civil Engineers, May 25. 1905.

COST OF DEVELOPMENT AND RENTAL OF WATER POWER IN NORTH AMERICA IN THE PAST SIX YEARS.

The following references result from an examination of: Transactions American Society of Civil Engineers, Vol. 1 to 63, inclusive; Transactions New England Cotton Manufacturers' Association, Vol. 48 to 80, inclusive; Transactions American Society of Mechanical Engineers, Vol. 1 to 27, inclusive; Engineering Index, Vol. 1 to 5, inclusive; Engineering News, Vol. 1 to 52, inclusive; Catalogue of the Library; Technical Index, American Society of Civil Engineers, May, 1906, to October, 1909, inclusive; Engineering Magazine Index, 1908, to August, 1909, inclusive; October and November, 1909.

ARTICLES GIVING DEFINITE FIGURES.

Niagara Power in Buffalo. I. Electrical World and Engineer, Vol. 44, p. 933, December 3, 1904. (Distribution of electrical energy by the Cataract Power and Conduit Company; cost to consumers, etc.; an article of three pages.)

Hydro-Electric Power Development at and near Joliet, Ill., using Chicago Drainage Canal Water. By Thomas T. Johnston. Journal of the Western Society of Engineers, Vol. 9, p. 295, June, 1904. (A discussion on the value, cost of development, etc., of the water power of this canal.)

The Spier Falls Dam of the Hudson River Water Power Company. Engineering News, Vol. 49, p. 552, June 18, 1903. (Gives the financial resources of the company and a statement of contracts for power with seven different companies.)

An Analysis of the "Commercial" Value of Water Power per Horse-Power per Annum. By A. F. Nagle. Transactions American Society of Mechanical Engineers, Vol. 24, 1903, p. 286. (Gives table of cost, etc., illustrated by examples from different companies; income received, etc., and comparison with cost of steam power.)

Extract of the same. Engineering News, Vol. 49, p. 83, January 22, 1903.

Water Resources of the State of New York. Part II. By George W. Rafter. Water Supply and Irrigation Papers of the United States Geological Survey, No. 25, 1899. Washington: Government Printing Office. (Gives value and selling price of water power in New York state.)

Electric Power Transmission. By J. W. Gore in "Paper on the Water Power of North Carolina," p. 335. North Carolina Geological Survey Bulletin No. 8, 1899, Raleigh, N. C. J. A. Homes, state geologist. (Includes relative cost of direct steam power and electrically transmitted power, with examples of some typical manufacturing plants.)

Report on Water Supply, Water Power, the Flow of Streams, and Attendant Phenomena. By C. C. Vermeule, p. 321, Vol. III of the Final Report of the State Geologist, Geological Survey of New Jersey, 1894. Henry B. Kümmel, state geologist, Trenton, N. J. (Gives relative cost of water-power and rental value per horse-power of the leading water powers of the United States.)

Electrical Equipment of the Consolidated California and Virginia Mining Company, Nevada. By L. M. Hall. Minutes of the Proceedings of the Institute of Civil Engineers, Vol. 152, 1902–03, Part 2, p. 430. (A short abstract from Electrical Review, New York. Vol. 41, pp. 298–302, September 6, 1902. The charge for power is $7 per horse-power per month, only one fourth of the cost of power generated locally.)

Electrical Equipment of the C. & C. Shaft, Virginia City, Nev. By L. M. Hall. Engineering Record, Vol. 46, p. 171, August 23, 1902. (The Truckee River General Electric Company sells power to the various mining companies at $7 per horse-power per month, the amount used being based on a maximum peak load of two minutes' duration.)

The Hydraulic Features of the Chambly Water Power. Engineering Record, Vol. 40, p. 50, June 17, 1899. (The total cost of development, exclusive of electrical machinery, was about $28 per horse-power.)

The Water Power at Holyoke. By Albert F. Sickman. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 18, p. 337, December, 1904. (The cost to the mills of surplus power is about $23 per year per horse-power; the rate paid for permanent power is something below $5 per year.)

The Chateaugay Water Power in the North Country. Electrical World and Engineer, Vol. 42, p. 831, November 21, 1903. (The rate for motors has been put at $20 per year per horse-power.)

Largest Electric Water Power in Maine. Electrical World and Engineer, Vol. 45, p 675, April 8, 1905. ("It is the intention to attract a very large motor load to the distributing lines in Lewiston and Auburn, and to this end consumers who use a maximum of 20 HP. will be supplied at the rate of $30 per horse-power a year of 3 000 hours of operation, as a flat rate. A consumer who uses 30 HP. or over at maximum load can purchase electric current at a flat rate of $25 per horse-power a year of 3 000 hours.")

The Water Power at Holyoke, Mass. By Horatio A. Foster. Journal Association of Engineering Societies, Vol. 25, p. 67, August, 1900. (Gives cost of development of water power and price to consumers.)

Power Transmission Plant in the Maine Woods. Electrical World and Engineer, Vol. 33, p. 537, April 29, 1899. (A description of the plant belonging to the Cumberland Illuminating Company of Portland, Me., and the price charged for the power, etc.)

St. Cloud, Minn., Water Power Plant. By F. W. Springer. Electrical World and Engineer, Vol. 34, p. 481, September 30, 1899. (Price of renting the water power, etc.)

The Catawba River Power Development near Rock Hill, S. C., I–II. By C. A. Mees. Engineering Record, Vol. 50, pp. 114, 129, July 23, 30, 1904. (Cost of development was $110 per horse-power.)

Cross Country Line at Lewiston, U. S. A. Minutes Proceedings Institute of Civil Engineers, Vol. 138, p. 557, 1898–99, Part 4. (A very short abstract from article in the Electrical World, Vol. 33, 1899, pp. 255–258; power for the railway is obtained from falls near Brunswick, where 1 000 HP. has been leased for $10 000 per annum.)

ARTICLES CONTAINING ESTIMATES.

Modern Turbine Practice and Water Power Development. II. By John Wolf Thurso. Engineering News, Vol. 49, p. 26, January 8. 1903. (Gives a few general figures on the cost of water power, intended to apply to conditions at present prevailing in the northern part of the United States and in Canada, including cost of plant and price charged for water power per gross horse-power per year.)

A Project for Developing the Water Power of the Des Moines Rapids. Engineering News, Vol. 46, p. 373, November 14, 1901. (Gives estimates of cost of dams, etc., cost of power station, and results; compares figures with average cost of steam power for location in the upper Mississippi Valley. A long article.)

Notes and Queries. Engineering News, Vol. 48, p. 171, September 4, 1902. (A very short paragraph in answer to the query as to the amount of water power in the United States; the prices to which power is sold vary probably from $10 to $100 per horse-power per annum.)

Work on the Development of Water Power in the Chicago Drainage Canal. Engineering News, Vol. 48, p. 89, August 7, 1902. A very short paragraph. The estimated cost of a plant that will develop 24 000 HP. is about $3 000 000; it is expected to yield an annual income of $600 000.)

The Influence of Electricity on the Development of Water Powers. By F. A. C. Perrine. Transactions of the New England Cotton Manufacturers' Association, No. 75, 1903, p. 101. (On the establishment of central power stations in New England; gives a theoretical value of water power per horse-power.)

Commercial Development of Water Power. By Alton D. Adams. Cassier's Magazine, Vol. 27, p. 152, December, 1904. (Illustrates from actual practice some of the conditions that are met and some of the considerations that govern in the development of water powers for electrical supply from a financial point of view.)

Electricity from Water Power versus Gas. By Alton D. Adams, Cassier's Magazine, Vol. 27, p. 478, April, 1905. (Compares the price of electricity and gas; as low a rate as 1 cent per kilowatt-hour is not infrequently made in the hydraulic-electric system; gives no practical examples of its use: a short article.)

Some Details Entering into the Computation of the Values of Water Powers and the Damages Caused by the Diversion of Water Used for Power. By Charles T. Main. Transactions American Society of Mechanical Engineers, December, 1903. (Contains table of estimated costs per horse-power of water-power plants.)

Developing a Water Power, Elements of Financial and Commercial Success. By Thorburn Reid. Cassier's Magazine, Vol. 26, p. 419, August, 1904. (A theoretical treatment of the subject.)

Cost of Energy in Electrical Supply. By Alton D. Adams. Engineering Magazine, Vol. 24, p. 181, November, 1902. (A comparison of accurate figures from steam and water power stations, showing the influence of local conditions upon the elements of cost.)

Water-Power in Electrical Supply. By Alton D. Adams. Cassier's Magazine, Vol. 23, p. 326, December, 1902. (First cost and subsequent charges connected with development of water power.)

Commercial Analysis of Small and Unprofitable Electric Lighting and Power Enterprises. By William D. Marks. Electrical World and Engineer, Vol. 36, p. 321, September 1, 1900. (Gives income, etc., of several enterprises dealing with small accounts.)

Report on the Development of the Water Power of the Des Moines Rapids of the Mississippi River near Keokuk, Ia., and Hamilton, Ill. By Lyman E. Cooley. Paper. 1901. Published by the Keokuk and Hamilton Water Power Company, Keokuk, Ia. (Gives estimates of the cost of the development of the water power.)

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SEARCH FOR MATERIAL ON "COST OF DEVELOPMENT AND RENTAL OF WATER POWER IN NORTH AMERICA," NOVEMBER 13, 1909.

NOTE. — This is a continuation of Search No. 153. (Original search made May 25, 1905.)

These references result from an examination of the following: Engineering Index, 1905 to November, 1909, inclusive; Transactions American Society of Civil Engineers, Vols. 46 to 64, inclusive.

Hydro-Electric Power in Canada. By Cecil B. Smith, member American Society of Civil Engineers. Proceedings American Society of Civil Engineers, Vol. 35, p. 454, May, 1909. (Contains brief data on the rental of water power.)

The Economic Improvement of the Coosa and Alabama Rivers in Georgia and Alabama. By D. M. Andrews, member American Society of Civil Engineers. Transactions American Society of Civil Engineers, Vol. 50, p. 363, Paper 952, June, 1903. (Theoretical.)

The Hydraulic Plant of the Puget Sound Power Company. By Edwin H. Warner, member American Society of Civil Engineers. Transactions American Society of Civil Engineers, Vol. 55, p. 249, Paper 1007, December, 1905. (States that the total cost of work approximates $125 per horse-power, a portion of which is properly chargeable to preparation for the second installation of 20 000 HP., which, when made, will reduce the cost to approximately $90 per horse-power developed.)

Some Engineering Features of the Southern Power Company's System. By J. W. Fraser. Transactions American Institute of Electrical Engineers, Vol. 27, p. 819, 1908. (On the cost and rental of hydro-electric power.)

Southern Water Power Developments. Electrical World, Vol. 50, p. 1241, December 28, 1907. (The Southern Power Company charges $20 per horse-power per year for energy used eleven hours a day, six days in the week.)

Water Power Estimate. In Third Annual Report of the State Water Supply Commission of New York for year ending February 1, 1908, pp. 438, 483, 495. Albany, 1908. State Water Supply Commission, Henry H. Persons, president. (Estimates of cost and profit of water-power development in northern New York.)

Water Storage and Power Development. In Fourth Annual Report of the State Water Supply Commission of New York for the year ending February 1, 1909, p. 161. Albany, 1909. (Estimated cost and possible net annual revenue from undeveloped water power in New York state.)

Cost of Electric Power to Consumers. (Letter.) By Charles L. Jones. Electrical World and Engineer, Vol. 45, p. 350, February 18, 1909. (Cost of hydro-electric power made by the Cataract Power and Conduit Company.)

The Cost of Water Power. By Samuel Webber. Cassier's Magazine, Vol. 8, p. 415, August, 1895.

Electric Power Transmission. By Frederick Darlington. Transactions American Institute of Electrical Engineers, Vol. 25, p. 181, 1906. (Cost of development of water power.)

The Sale and Measurement of Electric Power. By S. B. Storer. Report of the Twenty-Fourth Annual Meeting of the Street Railway Association of the State of New York, 1905–06, p. 62. C. B. Fairchild, Jr., Secretary, 114 Liberty Street, New York. (Refers to hydro-electric power plants. Theoretical.)

Abstract of same. *The Sale and Measurement of Power.* By S. B. Storer. Engineering Record, Vol. 54, p. 495, November 3, 1906; Electrical Age, Vol. 37, p. 129, August, 1906.

The Sale of Water Power from the Power Company's Point of View. By C. E. Parsons. Report of the twenty-fourth annual meeting of the Street Railway Association of the State of New York, 1905–06, p. 77. (Describes the system of the Hudson River Electric Power Company.)

Abstract of same. Engineering Record, Vol. 54, p. 161, August 11, 1906.

The Ontario Hydro-Electric Power Commission at Ottawa. By J. A. Macdonald. Electrical World, Vol. 52, p. 720, October 3, 1908. (Gives rental of power in the city of Ottawa.)

Contracting for Use of Hydro-Electric Power on Railway Systems. By G. A. Harvey. Report of the twenty-fourth annual meeting of the Street Railway Association of the state of New York, 1905–06, p. 89. (Theoretical; analysis of rental of hydro-electric power.)

Abstract of same. Electrical Age, Vol. 37, p. 211, September. 1906.

Cost of Steam and Water Power in Montana. By M. S. Parker. Journal Association of Engineering Societies, Vol. 15, p. 26, July, 1895. (Gives charges for power at various places.)

The Cost of Niagara Power in Buffalo. Electrical World, Vol. 31, p. 499, April 23, 1898. (Statement by the Cataract Power and Conduit Company of their rates and reasons for making them.)

Analysis of Proposed Change in Power Contract. By Robert Sibley. Engineering and Mining Journal, Vol. 87, p. 794, April 17, 1909. (A system of penalties for peak loads, introduced by a northwestern water-power company.)

The Analysis of an Hydro-Electric Project. By H. von Schon. Journal Western Society of Engineers, Vol. 13, p. 687, December, 1908. (On the cost and rental of hydro-electric power.)

Hydro-Electric Practice. By H. A. E. C. von Schon, member American Society Civil Engineers, Philadelphia, 1908. J. B. Lippincott. $6 net. (Contains chapters on cost of development of hydro-electric power and value of project and presentation.)

Water Power Engineering, the Theory, Investigation, and Development of Water Powers. By Daniel W. Mead, member American Society of Civil Engineers, p. 646. New York, 1908. McGraw Publishing Company, 239 W. 39th Street. $6. (Contains a chapter on the cost, value, and sale of power.) (Dd-71.)

Water Power Development in the National Forests, a Suggested Government Policy. By Frank G. Baum. Transactions American Institute Electrical Engineers, Vol. 27, p. 475, 1908. New York, 1909. Ralph P. Pope, secretary, 33 W. 39th Street. (Theoretical article.)

Notes on Hydro-Electric Developments. By Preston Player. New York, 1908. McGraw Publishing Company, 239 W. 39th Street. $1 net. (Costs and profits of water-power development.) (Dd-70.)

The Cost of Hydro-Electric Power Development in the Province of Ontario. Engineering News, Vol. 58, p. 669, December 19, 1907. (Table of estimated cost of hydro-electric power development and annual charges per horse-power.)

Relation of Load Factor to Power Costs. By E. W. Lloyd, C. A. S. Howlett, and J. M. S. Waring. Journal Western Society of Engineers, Vol. 14, p. 241, April, 1909. (Theoretical.)

Some Fundamental Principles Underlying the Sale of Electrical Energy. By Clarence P. Fowler. Electrical World, Vol. 50, p. 456, September 7, 1907. (Discusses rental of hydro-electric power.)

Notes on Design of Hydro-Electric Power Stations (with reference to the Influence of Load Factor). By David B. Rushmore. Transactions American Institute of Electrical Engineers, Vol. 25, p. 145, 1906. (Cost and value of efficiency in power plant designing, general discussion.)

The Relation of Load Factor to the Evaluation of Hydro-Electric Plants. By S. B. Storer. Transactions American Institute of Electrical Engineers, Vol. 25, p. 139, 1906. (Theoretical.)

Abstract of same. Electrical World, Vol. 47, p. 669, March 31, 1906.

Relation of the Federal Government to Undeveloped Water Power on Navigable Streams. By J. E. Sirrine. Engineering Record, Vol. 60, p. 207, August 21, 1909. (Discusses in a general way the cost of developing water power.)

A Discussion of Various Methods of Charging for Electric Energy. By E. Richards. Transactions of the Engineering Society, University of Toronto, Vol. 20, p. 57, 1906–07. G. H. Moody, secretary, Toronto, Ontario, Canada. 50 cents. (The various methods of charging for hydro-electric and other plants and their effects upon load factor; theoretical.)

A Proposed Dam and Water Power on the Mississippi River at Keokuk, Ia. By Lyman E. Cooley. Journal Western Society of Engineers, Vol. 7, p. 10, February, 1902. (Estimated costs of developing a water-power project.)

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SEARCH FOR MATERIAL ON VALUATION OF WATER POWER, NOVEMBER 15, 1909.

NOTE. — Search No. 291 brought up to date.

Storage and Pondage of Water. By Joseph P. Frizell, member American Society Civil Engineers. Transactions American Society of Civil Engineers, Vol. 31, pp. 29, 552. January, May, 1894. (On the valuation of water power.)

The Cost of Steam Power. By Charles E. Emery, member American Society of Civil Engineers. Transactions American Society of Civil Engineers, Vol. 12, p. 425, November, 1883. (In a suit respecting the loss of power by the diversion of water, damages were claimed by the mill owners based on the cost of purchasing, operating, and maintaining at each mill a small engine, and a complete independent steam plant.)

Calculations of the Mean Horse-Power of a Variable Stream and the Cost of Replacing the Power Lost by a Partial Diversion of the Flow. By William H. Grant, member American Society of Civil Engineers. Transactions American Society of Civil Engineers, Vol. 22, p. 389, June, 1890. (In regard to claims of property owners for diversion of part of the waters of the Bronx River.)

The Value of Water Power. (Editorial.) Engineering Record, Vol. 33, p. 597, May 9, 1896. (Two columns.)

An Analysis of the "Commercial" Value of Water Power per Horse-Power per Annum. By A. F. Nagle. Transactions American Society of Mechanical Engineers, Vol. 24, p. 286, 1903. (With discussion.)

Abstract of same. Engineering News, Vol. 49, p. 83, January 22, 1903.)

Computation of the Values of Water Powers and the Damages Caused by the Diversion of Water Used for Power. By Charles T. Main. Transactions American Society of Mechanical Engineers, Vol. 26, p. 68, 1905. (Gives definitions of value and damage and method of determining value.)

Abstract from the Report of the Water Commissioners, Troy, N. Y., Damages to Mill Powers. By William G. Raymond. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 13, p. 152, December, 1898. (On the method of estimating value of damages.)

A Method of Estimating the Loss of Water Power in a Stream by Taking Water Therefrom for a City Supply. By L. M. Hastings. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 7, p. 187, June, 1893. (Discussion on the value of the water power.)

Abstract of same. Engineering Record, Vol. 27, p. 296, March 11, 1893.)

Cost of Steam and Water Power. By Charles T. Main. Transactions American Society of Mechanical Engineers, Vol. 11, p. 108, 1889. (On the value of water power; no reference to condemnation proceedings.)

Comparative Cost of Steam and Water Power. By Charles H. Manning. Transactions American Society of Mechanical Engineers, Vol. 10, p. 499, 1889. (On the value of water power.)

The Value of a Water Power. By Charles T. Main. Transactions American Society of Mechanical Engineers, Vol. 13, p. 140, 1891. (On the method of estimating the value of water power with relation to condemnation proceedings.)

On the Value of a Horse-Power. By George I. Rockwood. Transactions American Society of Mechanical Engineers, Vol. 21, p. 590, 1900. (On the dispute between the city officials of Worcester and the mill owners on the loss of power by the diversion of water for the Worcester reservoir.)

Relation of Steam to Water Power. By James G. Hill. Transactions New England Cotton

Manufacturers' Association, Vol. 65, p. 333, 1898. (Contains a table giving yearly cost of one horse-power of water.)

Valuation of Manufacturing Property for Taxation. By Charles T. Main. Transactions New England Cotton Manufacturers' Association, Vol. 67, p. 108, 1899. (Contains data on the method of determining the value of water power.)

Water Power, Its Measurement and Value, with Data Respecting Damages Awarded. By George A. Kimball. Journal Association of Engineering Societies, Vol. 13, p. 71, February, 1894. (Paper read before the Boston Society of Civil Engineers. Some of the facts presented in evidence before the commission to award damages in the city of Waltham, Mass.)

Water Power at Niagara Falls. By Samuel McElroy. Journal Association of Engineering Societies, Vol. 4, p. 395, September, 1885. (Estimation of the value of water power by commissioners to award damages.)

Water Power. In Geological Survey of New Jersey. Final Report, Vol. 3. By Henry B. Kümmel, State Geologist, Trenton, N. J., 1894. (Data on the cost of water power.)

Nashua River Paper Company v. *Commonwealth of Massachusetts*, 4 volumes, Boston, 1901. Wright & Potter Printing Company, 18 Post Office Square. (On damages to be awarded for drawing off the water flowing by the plaintiff's mills.) (Dd-38.)

Report on the Water Power of the Rock River at Sterling and Rock Falls, Ill., and the Probable Effect on the Power of the Diversion of Water for Feeding the Illinois and Mississippi Canal. By Daniel W. Mead, Chicago, Ill., 1904. The author, First National Bank Building. (Gives the value of water power destroyed by diversion of water.) (Dd-44.)

Kettle Brook and Blackstone Valley Mill Owners, Petitioners v. *City of Worcester*, 5 volumes, Worcester, 1899. (Final arguments in a suit on the loss of power from the diversion of water.) (Dd-40.)

Boston Belting Company v. *City of Boston*, 39 volumes, pamphlets, Boston, 1899. (Suit relates to the diversion of water from Stony Brook and the value of the water power.) (Dd-39.)

Holyoke Water Power Company v. *City of Holyoke*, 20 volumes, Boston, 1899. George H. Ellis, 272 Congress Street. (Suit in regard to the value of the water power.) (Ia-28.)

Value of New England Water Power. (Editorial note.) Engineering News, Vol. 43, p. 49, January 25, 1900.) Contains a table taken from the Providence *Journal.*)

Water Power of Caratunk Falls, Kennebec River, Maine. By Samuel McElroy. Transactions American Society of Mechanical Engineers, Vol. 17, p. 58, 1895-96. (On the relative cost of steam and water power.)

Abstract of same. Engineering News, Vol. 34, p. 422, December 26, 1895.

Computation of the Value of Water Powers and the Damages caused by the Diversion of Water Used for Power. By Charles T. Main. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 21, p. 214, September, 1907. (Contains a table of estimated costs per horse-power of water power plants.)

Damages Caused by the Diversion of Water Power. By Clemens Herschel. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 21, p. 241, September, 1907. (On methods of estimating market value of water power.)

Water Rights. By Richard A. Hale. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 21, p. 248, September, 1907. (The discussion of this paper relates to the valuation of water power.)

Notes on Design of Hydro-Electric Power Stations with Reference to the Influence of Load Factor. By David B. Rushmore. Transactions American Institute of Electrical Engineers, Vol. 25, p. 145, 1906. (The discussion of costs is confined to general principles; definite values are not given.)

Electric Power Transmission. By Frederick Darlington. Transactions American Institute of Electrical Engineers, Vol. 25, p. 181, 1906. (Cost of developing and maintaining hydro-electric power employed in mill work in comparison with steam power.)

The Relation of Load Factor to the Evaluation of Hydro-Electric Plants. By S. B. Storer. Transactions, American Institute Electrical Engineers, Vol. 25, p. 139, 1906. (Contains diagrams giving comparative cost of steam and hydro-electric plant.)

The Sale and Measurement of Electric Power. By S. B. Storer. Street Railway Journal, Vol.

27, p. 1018, June 30, 1906. (Contains diagrams giving methods of plotting costs and price, per horse-power per year, of steam or hydro-electric power.)

The Cost of Hydro-Electric Power Development in the Province of Ontario. Engineering News, Vol. 58, p. 669, December 19, 1907. (Tables of cost from the report of the Hydro-Electric Power Commission of the Province of Ontario.)

The Value and Design of Water Power Plants as Influenced by Load Factor. By Frederic A. C. Perrine. Journal of the Franklin Institute, Vol. 162, p. 269, October, 1906.

Sale of Water Power from the Water Power Company's Point of View. By C. E. Parsons. Street Railway Journal, Vol. 27, p. 1023, June 30, 1906.

Cost of Generating Electric Power. By F. A. Griffin. Street Railway Journal, Vol. 26, p. 1142, December 30, 1905. (Gives diagram of maintenance of generating station and states that the cost of generating power by water can be found from the diagram by eliminating the cost of coal.)

The Developments of Water Power in the Province of Ligure, Italy. Electrical Review, London. Vol. 59, p. 454, September 21, 1906. (Gives cost of developing the power.)

Hydraulic Developments as Related to Electric Installations. By William B. Jackson. Journal of the Western Society of Engineers, Vol. 8, p. 312, June, 1903. (Entirely theoretical.)

Modern Turbine Practice and Water-Power Plants, p. 196. By John Wolfe Thurso, New York, 1905. D. Van Nostrand Company, 23 Murray Street. $2 net. (Contains one page on cost of water power.) (Dd-53.)

The Comparative Cost of Steam and Hydro-Electric Power. By William O. Webber. Engineering Magazine, Vol. 33, p. 889, September, 1907.

Hydro-Electric Power v. Steam for Industrial Purposes. By H. von Schon. Engineering Magazine, Vol. 33, pp. 34, 184, 353, April, May, June, 1907. (A comparison of costs of hydro-electric and steam power in developed and undeveloped plants.)

Contracting for Use of Hydro-Eleetric Power on Railway Systems. By G. A. Harvey. Street Railway Journal, Vol. 27, p. 1016, June 30, 1906.

Electric Transmission of Water Power, p. 1. By Alton D. Adams. New York, 1906, McGraw Publishing Company. $3. (Two chapters on water power and its utility in electrical supply relate to the cost of water power.) (Hc-66.)

Design and Construction of Hydro-Electric Plants, p. 45. By R. C. Beardsley. New York, 1907, McGraw Publishing Company. $5 net. (Contains four pages on the relation of pondage and reservoirs to the valuation of power.) (Dd-56.)

High-Tension Power Transmission, Vol. 1, p. 434. New York, 1905, McGraw Publishing Company. $3. (A comparison of the cost of steam and water power. In discussion on "Maximum Transmission Distance." By Ralph D. Mershon. Read before the American Institute of Electrical Engineers.) (Hc-68.)

The Adjustment of Diversion Damages by Storage Compensation. By Robert E. Horton. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 22, p. 334, September, 1908.

Proposed Compensation in Kind for Water Diverted for the Supply of Norwich, Conn. By Hill, Quick, and Allen. Engineering News, Vol. 45, p. 381, May 23, 1901. (Outline of a plan for compensating mill owners.)

An Important Decision Upon a Mill Owner's Suit to Collect Damages for the Diversion of Water. By Louis L. Tribus. (Letter.) Engineering News, Vol. 43, p. 228, April 5, 1900. (Gives text of decision in the case at Newton, N. J.)

The Appraisal and Depreciation of Water Works and Similar Properties. By William H. Bryan. Journal Association Engineering Societies, Vol. 39, p. 336, December, 1907. (Methods of valuation.)

Compensating Reservoirs for Gravity Water Supplies in Lieu of Compensation for Riparian Rights and Its Legal Aspects. By S. E. Babcock. Proceedings American Water-Works Association, Vol. 18, p. 101, 1898.

The Value of Water. By Alton D. Adams. Municipal Engineer, Vol. 37, p. 77, August, 1909. (Decision of the Massachusetts court as to the general rule of compensation where water is taken under legislative authority for public use.)

Notes on Newton, N. J., Water-Works Construction and Litigation. By Louis L. Tribus. JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 23, p. 145, June, 1909. (Decision of court as to valuation of water power diverted for Newton, N. J., water works.)

DISCUSSION.

Mr. Leonard Metcalf.* In comment upon the work of the committee, it may be asked why we took the seventh month in order of dryness as a basis in figuring available power. Our reason was that that figure seems to represent the average practice in New England. At the same time you must bear in mind the fact that the wheel development on any stream at any privilege will depend upon the use to which it is to be put.

I also want to caution you in regard to the use of the figure 1.4 cubic feet per second run-off of water corresponding to the flow of the seventh month arranged in order of dryness, which refers to the maximum wheel development. That does not imply, of course, that you actually get the power corresponding to that flow of water throughout the year. It simply means that you have a wheel installation to utilize that amount of water; you get the power that may be generated from the actual flow in the stream. The average amount will be the power corresponding more nearly to a flow one cubic foot of water per second per square mile of tributary watershed under the conditions prevailing in New England streams.

In regard to the Sudbury River records to which we have referred, we believe that the record of the period up to and including 1897 is more accurate than the later period, for the reasons stated. The water coming from the Nashua River, flowing through the Sudbury basin, has to be measured in and out, and as Boston is now using about one hundred and twenty million gallons of water a day, you can see that an error of one or two per cent. in the measurement of the quantity of water flowing, distributed back on to 75 square miles of the Sudbury River watershed, introduces quite an error. This and the further fact that account is not made of the actual evaporation from the existing water surface of the present basins is the explanation for the negative yields which we have had from this watershed, particularly since the year 1897.

One word in regard to the range of awards for diversion of water per square mile per foot of fall. To tell you that these results range from $2 to $360, or whatever the exact figure is, per square mile per foot of flow does not mean much. But I think when you

* Of Metcalf & Eddy, Consulting Engineers, Boston, and Secretary of the Committee on Awards.

are given the average results, and the results which have been obtained in certain privileges with which you are conversant, you will be able to take the individual results and make a reasonably close estimate of the damages which are likely to accrue in any locality in New England for water diverted. Thus, for instance, you will find on studying these results, for the more remote privileges, and of low fall, which have not been highly developed and are used for grist mills and similar plants, values of from $10 to $15; for a little more specialized use, $25; and taking such uses as we find on Blackstone River in the Kettle Brook and Woonsocket cases, where the award was about $137, we may say that the award is likely to range from $125 to $150 per square mile of tributary watershed per foot of fall. So, after all, I think you will find that the records given you, with the detailed information, are sufficiently specific to enable you to discriminate intelligently between the conditions existing upon your own privilege and those cited by us, and to determine the applicability of the different results given you.

In the case of abandoned and unused privileges, we find that the general results range from $1 or $2 for remote privileges to perhaps $10 to $20 per square mile of tributary watershed per foot of fall for privileges advantageously located, but which have been abandoned.

I think that is all that I wanted to call to your attention. If our report shall assist in keeping you out of litigation, we shall feel amply repaid.

Mr. H. K. Barrows.* The report of this committee is most interesting and a valuable contribution to the records of this Association.

In using only the Sudbury, Croton, and Nashua records of run-off, the committee have very properly stated that their deductions regarding the average discharge of streams in New England are only roughly approximate. It seems to me that this statement should be further accentuated and kept clearly in mind. Perhaps it would be safer to state further that the conclusions of the committee in this respect are based wholly upon the run-off of three streams in southern New England (and New York) which are not

* Of Barrows & Breed, Consulting Engineers, Boston, Mass.

applicable to many other streams in this part of New England to, say nothing of those in the northern New England states.

The measurement of run-off of streams in New England by the United States Geological Survey has been carried on now for several years, and even a superficial examination of their records indicates very wide variations in run-off in different sections of New England.

Thus in the Berkshires of western Massachusetts records have been kept sufficiently long to indicate that a much higher average run-off occurs there than in the Nashua and Sudbury region. The upper Deerfield basin is especially noteworthy in this way, and an examination of precipitation records in that vicinity indicates a decided increase in amount at the higher elevations, thus increasing the run-off of streams heading in this mountain range.

This increase in precipitation with altitude in New England is very well shown by the records kept on the summit of Mt. Washington by the United States Weather Bureau. The mean annual precipitation here over a period of fifteen years was 83.5 inches, or about double that at the lower altitudes. Very high precipitation occurs here in the summer months, and the regimen of streams heading in the White Mountains is decidedly different from that of the Sudbury and Nashua or other streams in southern New England.

In the state of Maine some very good records of run-off have been obtained, which also show marked differences in regimen of flow. Here many of the rivers are affected by storage, and this factor is of great importance in planning water-power developments.

To show in a general way the variation in run-off of New England streams, I have arranged the following tables, which include data at some of the stations of the United States Geological Survey as prepared for a special report to the United States Conservation Commission in 1908, supplemented by data obtained during 1908.*

The stations in Maine have been considered as one group and those in the remaining New England states as a second group.

* From manuscript of Water Supply Paper No. 241, United States Geological Survey, by permission of the Director.

TABLE I.

MEAN YEARLY RUN-OFF AT RIVER STATIONS IN THE STATE OF MAINE, 1900–1908 INCLUSIVE.

Station.	Drainage Area. Square Miles.	Mean Annual Run-Off in Sec. Feet per Square Mile.
Fish River, Wallagrass	890	1.48
Aroostook, Fort Fairfield	2 230	1.89
St. Croix, Woodland	1 420	2.45
Machias, Whitneyville	465	2.28
Penobscot, Millinocket	1 880	1.72
Mattawamkeag, Mattawamkeag	1 500	2.07
Piscataquis, Foxcroft	286	3.00
Kennebec, The Forks	1 570	2.03
Moose, Rockwood	680	1.64
Sandy, Madison	650	1.62
Cobbosseecontee, Gardiner	240	1.36
Androscoggin, Rumford Falls	2 090	1.68
Presumpscot, Sebago Lake	420	1.49
(1) Mean of Maine Group		1.90
Maximum		3.00
Minimum		1.36
(2) Mean of Sudbury-Nashua		1.66
Ratio $\frac{(1)}{(2)}$, mean		1.15
,, maximum		1.81
,, minimum		0.82

TABLE II.

MEAN YEARLY RUN-OFF AT RIVER STATIONS IN NEW ENGLAND, EXCEPTING MAINE, 1900–1908 INCLUSIVE.

Station.	Drainage Area. Square Miles.	Mean Annual Run-Off in Sec. Feet per Square Mile.
Saco, Center Conway, N. H.	385	2.65
Merrimac, Franklin, N. H.	1 460	2.09
Pemigewasset, Plymouth, N. H.	615	2.57
Nashua, Clinton, Mass.	119	1.77
Sudbury, Framingham, Mass.	75	1.55
Connecticut, Sunderland, Mass.	7 700	1.79
Housatonic, Gaylordsville, Conn.	1 020	2.09
Otter Creek, Middlebury, Vt.	615	*1.58
Winooski, Richmond, Vt.	885	*1.76
(1) Mean of group		1.98
Maximum		2.65
Minimum		1.55
(2) Mean of Sudbury-Nashua		1.66
Ratio $\frac{(1)}{(2)}$, mean		1.19
,, maximum		1.60
,, minimum		0.94

The stations in the foregoing tables are not located so as to give a true mean value of the yearly run-off in the two districts considered, as many more stations are needed, with more general distribution, to accomplish this result. The mean value obtained for the state of Maine is better than that for the other district, but the tables are chiefly valuable in showing the great variation in run-off in different portions of New England.

A percentage comparison is made in both cases with the Sudbury-Nashua mean run-off, and the futility of applying the latter records generally to New England drainage areas is very apparent. (The figures of run-off of the Croton River, 1900–1908, are not available. The run-off of the Croton is similar to that of the Sudbury, however, and probably little difference has been occasioned thereby.)

It will be many years before the United States Geological Sur-

* For the period 1900–1906, inclusive.

vey will have obtained records of run-off at a sufficient number of stations in New England to cover all water-power sites, but it should be kept in mind that these data are being accumulated as fast as conditions will allow, and even now data are at hand in many cases which are much better applicable than the time-honored Sudbury-Nashua-Croton records, which, while accurate in themselves, are often used for drainage areas and hydrologic conditions entirely at variance with conditions upon these three drainage basins.

Mr. E. L. Grimes.* I have been engaged in defending my city more or less intermittently in cases for six or seven years, and I fully agree with the conclusion that this committee has come to with regard to getting a standard by which these cases can be adjusted. I find it very difficult, even upon the same stream, to find any two cases which will bear such relation to each other that they can be well compared. Cases are brought sometimes which seem unreasonable and ridiculous. For instance, there is one case I have in mind where an ice company, which simply rented the privilege of cutting ice from a pond fed by a stream, the upper waters of which the city diverts, brought in a claim of $20,000 for the diversion of the water. The water is not sufficiently diverted from the stream to prevent them from cutting as much ice on the pond as usual. They have no rights in the pond except those that they have leased from other parties who can cut them off from the pond at any time they choose.

I occasionally run across some amusing claims which involve new and interesting hydraulic principles. For instance, one of the mill owners insisted that as a result of his observation during a long period of years he knew that he could do more work during the night hours than he could during the day hours, and the reason he gave for it was that the water was heavier at night than it was in the day.

Another case, where I was quite interested to know what the decision of the court would be, was a case where a man owned the bed of a pond. The pond is a natural pond, and the man acquired the bed. He afterward wished to raise his dam, and he acquired the rights of the property owners above him to high-water mark

* City Engineer, Troy, N. Y.

of the proposed new reservoir. The city has taken the reservoir which this man built and the rights which he had acquired. The parties adjacent to this pond, who own the land above the high-water mark, all claim riparian rights in this water. I am interested to know whether the parties about the pond have any riparian rights, and if they do have when the pond is at high-water mark,— if they have riparian rights then, due to the fact that their property abuts upon the water, — whether they would have any such rights if the water was drawn down a foot or two, leaving a strip of land between their property and the water.

Mr. R. E. Horton (*by letter*).* This general subject is of great interest and importance both to water-works and water-power engineers. To a layman it would certainly appear that there was a very wide discrepancy in the values of water powers arrived at in different cases, and furthermore that there was, as a rule, just as much difference between the values awarded for water powers in condemnation proceedings and the prices at which sales and transfers actually take place between private parties. The writer has frequently been asked the question by a prospective client, "How much is a horse-power worth?" It seems to me that a proper reply to this sort of question is, Yankee fashion, to ask another question, as, for example, "How much is a farm worth?" In other words, there is no fixed value applying to all water powers any more than there is any one fixed value applying to all farm lands, and for the same reasons.

In a paper presented before the American Water Works Association in 1909, and which will shortly be published in their proceedings, the writer has attempted to correlate the different conditions commonly arising in questions of valuation of water power, and to deduce some general conclusions therefrom. Inasmuch as the writer's views will be shortly presented in this form it does not seem advisable to elaborate them here to any extent. One principle which has been very helpful to the writer in arriving at a proper basis of valuation may be briefly stated as follows: The value of a horse-power of water power at any place is closely related to the market value in that locality of whatever form of power is sufficiently common or so extensively used as to generally

* Hydraulic Engineer, Albany, N. Y.

predominate and rule the market. For example, in a region where water power was very scarce, and extensive manufacturing was carried on almost exclusively by steam power, a water power might be of great value. On the other hand, an entirely similar water power located in a region where large water powers were abundant, where nearly all manufacturing was carried on by water power, and where there was still remaining undeveloped power, in such a case the value of the water power might be very much less than in the former case. In the former case the value of the water power might very probably be arrived at by estimating the cost of substituting steam therefor. In the latter case the cost of substituting steam in place of the water power would have little or no bearing on the question. It seems to the writer that many experts have made a mistake by applying the method of steam substitution to the estimation of water-power values in all cases regardless of the attendant conditions. This is one source of the widely discordant values offered by opposing experts in condemnation proceedings. Even if their methods were entirely similar, it could not be expected that experts on opposite sides would agree very closely in their valuations, because there are always many matters of judgment, and not infrequently questions of doubt involving legal interpretation. The expert must, of course, fix his value to meet the legal hypothesis of the attorneys and is, as it seems to the writer, entitled to construe questions of doubt in favor of his client. Finally, it appears to the writer that the valuation of water power, even when subjected to careful, honest investigation by experienced men, is a matter of great difficulty and uncertainty. It does not appear evident how any general method can be formulated that is applicable to all cases. It seems to the writer to be necessary that each case should be made a subject of special study, and that ultimately the matter of valuation resolves itself into a question of good judgment.

Mr. Arthur T. Safford (*by letter*).* The report of this committee is, I believe, the first attempt to tabulate publicly awards and settlements of this character and bring them down to a uniform basis. I think the members of the committee should be asked to continue their labors and get additional statements, which should

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* Consulting Engineer, Lowell, Mass.

be forthcoming from other engineers who will begin to realize the amount of work the committee has already done and the value which will result from these statistics.

The committee has made it perfectly clear that all these figures should be used with great care, and that it is not worth while to attempt to reconcile too many apparent inconsistencies. There is, however, the danger that these statistics may, in the future, attempt to take the place of a careful working out of the conditions affecting the value of water power in new cases; and it may not be out of place in the discussion to call attention to some elements which get undue weight in these cases, and bring out other elements which may help to reconcile the differences pointed out by the committee.

There has been a tendency, I think, on the part of engineers, in cases involving litigation, to produce results based upon the Sudbury, Nashua, or Croton River figures, where no attempt has been made to get at the actual power available at a given mill site, except so far as the estimated average flow in cubic feet per second per square mile has been multiplied by the drainage area, the fall, and a power factor. Sometimes the wettest months are thrown out, but rarely is the flow from year to year followed out; and a statement is made, usually without figures, that in dry weather the twenty-four-hour flow may be concentrated into a smaller number of hours; this statement has been thought sufficient in certain cases to warrant the use of a ratio between twenty-four hours and the working time of the mill, and the ratio used as a factor to more than double the apparent power at the mill. This, I think, is a most dangerous practice, and the result has usually been to derive figures, which were beyond even the wheel development at the mill, which usually comprises one or two spare wheels, and to make the part of the water power diverted, on a reasonable basis of value, more than the entire water power is worth and throw discredit upon all the figures. The same is true of a great many reports upon new water powers, and investors are often absolutely deceived because a moderate price for the water power to be sold is joined with figures of flow and power which are, consciously or unconsciously, padded beyond reason.

There is no reason why this condition should exist because the

facts can be obtained and there is an opportunity to study, not only the figures of flow from drought to freshet and just how the water comes to the mill in the different seasons through the twenty-four hours, but also what use is made of it and what the net result will be, and if the value of the power is based upon what may be called the permanent power at a fair price for power for each kind of industry, and a distinction made between this and surplus power, not only will the figures be reasonable ones, but a tabulation of these awards such as we have from the Committee on Awards would probably represent very closely the actual value.

There are at least four different kinds of water powers, each one of which has its own peculiar elements of value, but which cannot very well be classed together, under any consideration of power. The same stream, moreover, at its different water power sites will gain or lose elements of value which will affect its total value materially. The four classes I have in mind particularly are as follows:

1. A water power on a stream like Winnepesaukee River, in New Hampshire, or the outlet of Sebago Lake, in Maine, where the storage is so great that, excepting in very dry years, the power is practically continuous without drought or freshet conditions. The best use of such a power is twenty-four hours continuously.

2. Water power for twenty-four hours continuously on a large stream like the Connecticut River, at Bellows Falls, Vt. In this case the river is practically without storage and, until recently, without large mill ponds. This condition carries with it extreme freshets and droughts.

3. Water power on a large stream like the Merrimac River at Lowell, Mass., and the Hudson River at Spier Falls, N. Y., where there is moderate storage and the pondage is sufficient to store the dry weather flow during the one hundred and sixty-eight hours in the week for use in something less than seventy-two hours. This condition carries with it moderate freshets and droughts.

4. Water power on a small stream like the Concord River at Lowell, Mass., where the water is sent down from one water power to another through small mill ponds and where the power is not constant. This particular stream has little deep storage, but is not subject to great freshets on account of swamps.

These four examples are given merely to bring out some of the differences which go to make power at the different mill sites; and the computations given are carried one step further than the figures given in the report of the committee, in order to introduce the element of time and show a product by the number of hours in which the power can be used. I have used in each case not an extreme minimum, but a period when the particular power was actually tested out at a very low time, and the figures are actual ones. The calculations with some conditions affecting the flow and power are as follows:

1. Sebago Lake, Maine: Drainage area, 420 square miles; storage capacity, said to be 7 500 000 000 cubic feet; ordinary use for power, twenty-four hours; flow for March, 1905, 343 cubic feet per second, or 0.817 cubic feet per second per square mile of drainage area.

The power for a day "per square mile per foot fall" would be 0.817 c.f.p.s. × .085 (power factor) × 24 hours = 1.667 h.p. hours.

2. Connecticut River at Bellows Falls, Vt.: Drainage area, 5 211 square miles; storage capacity, practically none; pondage, practically none; ordinary use for power, twenty-four hours; flow for August, 1909, 1 470.9 cubic feet per second, or 0.282 cubic feet per second per square mile of drainage area.

The power for a day "per square mile per foot fall" would be 0.282 c.f.p.s. × .085 (power factor) × 24 hours = 0.575 h.p. hours.

3. Merrimac River at Lowell, Mass.: Drainage area, 4 097 square miles; storage capacity, 5 000 000 000 cubic feet in Lake Winnepesaukee and other lakes; pondage, 200 000 000 cubic feet; ordinary use, ten to twelve hours; flow for August, 1909, 4 519.5 cubic feet per second, or 1.103 cubic feet per second per square mile of drainage area.

The power for a day "per square mile per foot fall" would be 1.103 c.f.p.s. × .085 (power factor) × 10 hours = 0.937 h.p. hours.

4. Concord River at Lowell, Mass.: Drainage area, 376.5 square miles, including Sudbury River; 301.3 square miles, excluding Sudbury River; storage, practically none below Sudbury River; pondage, practically none; ordinary use, ten to twelve hours; flow for August, 1909, 79.5 cubic feet per second, or 0.264 cubic feet per second per square mile of drainage area.

The power for a day "per square mile per foot fall" would be 0.264 c.f.p.s. × .085 (power factor) × 10 hours = 0.224 h.p. hours.

When the estimate of power is based upon average figures, the differences are not nearly so marked; these figures are not, however, given as estimates of power, but simply to bring out the effect of storage and pondage or the lack of them.

The four examples cited vary from a figure of 1.667 horse-power hours per day "per square mile per foot of fall" in the case of Sebago Lake to 0.224 horse-power hours in the case of the Concord River, the first named being more than seven times the other. Certainly when in the future most water powers are to be valued by their ability to produce a certain number of continuous horse-power or kilowatt hours at all times, it is fair to say that the drainage area, the flow per square mile, and the fall are not more important for estimating the power for commercial purposes at any given mill site than the storage and the pondage, and the value whether for purchase, sale, or assessing damages should not be complete without these other elements. This suggestion is not new and I do not mean that heretofore these elements have been entirely neglected; but it seemed wise in this discussion to again emphasize them so that they would not be lost sight of in the future.

THE UNDERLYING PRINCIPLES GOVERNING RIPARIAN WATER RIGHTS AND DIVERSION SUITS.

BY CHARLES F. CHOATE, JR., ESQ., BOSTON.

[*Read December 8, 1909.*]

It has been suggested that I read a paper as introductory to the discussion of the subject considered in the report made by the committee which has been investigating the subject of awards both by settlement and as the result of litigation for takings of water power. I take it that the first general matter to call to your attention is the nature of the right which a riparian owner possesses.

A man who owns land through which a stream of water flows has a right, which is incident to his ownership of the land, not to the water as property in and of itself, but a right to have that stream of water flow as it would flow under natural conditions, and to make such use of it while it passes through his land as it is possible and practicable to make without interfering with a similar right that is possessed by his next neighbors below him. That is a pretty broad and general definition of the right of a riparian owner, and there must be latitude in it, because the law is not an exact science, for it attempts only to give to individual human beings who may be possessed of different kinds of property those rights which common sense suggests they should be given.

It does not mean very much to say that a man is entitled to have a natural stream flow through his land as it naturally flows, because under present conditions of population and civilization there are many things which interfere, and have interfered, with the natural flow of streams, and which make their flow, as they exist to-day, different from what it was when the country was in a state of nature, as it were. For instance, the building of cities upon the banks of rivers undoubtedly changes to a very large degree the quantity of surface water that is contributed to the flow of any stream in that particular area, both in amount and

in the time when it is contributed, and in the place where it is contributed. The building of walls along the sides of streams must necessarily make a difference. The building of mills and dams upon streams, of course, makes a difference. But the meaning of that principle of law is that, taking the thing by and large, an owner of land through which a stream flows is entitled, as nearly as it is possible to obtain it, to the uninterrupted ordinary flow of the stream under the conditions which have naturally grown up along the borders of that stream. He has a right to use the water itself, that is, to consume the water itself, provided that his consumption does not materially diminish the quantity of water that is flowing in the stream. He has a right to divert it temporarily for irrigation or power or other purposes on his own land, provided he returns it to the stream substantially undiminished in volume or quality. He has the right to make use of it for ordinary domestic purposes. The little consumption, comparatively, that results from using the waters of the stream for a garden and for the ordinary purposes of agriculture, or for watering cattle, is so slight that the law does not recognize it as being an amount which in diminution of the volume of the water in the stream should be noticed, and for those purposes he has a right to use it.

Of course the most essential thing which he has the right to use it for, from an engineer's point of view, is for the development of power. It was long ago said, and is probably as true to-day as it was then, that the power that is incident to the ownership of any particular piece of land through which a stream flows is only the difference in level between the point where the stream enters the owner's land and the point where it leaves it. That, undoubtedly, is the natural right; the fall that exists upon a man's own land is all that under natural conditions he has a right to the enjoyment of. He may increase that right by two means: One by taking advantage of legislation, such as our Mill Acts, which give a man a right to erect a dam and to flow land not belonging to him above him, provided he does not interfere with anybody else's earlier established mill right, and pays damages for the flowage excess; and, secondly, he may increase his natural rights by what is called prescription, that is, by doing something which interferes with

somebody else's natural right for a period, usually twenty years or longer, so long that the law will presume that that right which he is claiming and exercising has been granted to him. If, for instance, he erects a dam upon his own land and flows not only his own land, but his neighbor's, and continues to keep that dam up and claims a right to keep it up and to flow his neighbor's land above him for twenty years, the law in most instances, without other explanation, would say that he had acquired the right to do it. So that, in addition to his natural right to the fall that exists upon his own property, he may increase the volume and value of the right that he possesses either by taking advantage of the provisions of the Mill Acts, or by exercising, under a claim of right, privileges or advantages which in time will grow into a right which he will possess himself.

Rather interesting questions arise relative to the extent of a man's right to the enjoyment of power where a number of mill privileges, dams, or reservoirs exist upon the same stream. Suppose, for instance, a stream which furnishes power, which has half a dozen successive mill rights one below the other. Of course, the man lowest down enjoys the storage which is accumulated by those higher up. If those higher up run their mills during the same period of the twenty-four hours that he does, he gets the accumulation without any expense to himself, and a number of cases have arisen in comparatively recent times which have dealt with the question of the right of the upper and lower proprietors. For instance, under modern conditions, where electricity is being manufactured, a man often wants to run his mill, his power, or his wheel either the whole of the twenty-four hours or during the night time, when the ordinary course is to use the power during the daytime, and the question has arisen between a man lower down the stream, whose business demands the use of water power during, say, ten hours of daylight, and some one up the stream who wants either to run his mill the whole twenty-four hours or to hold up the water during the daytime for accumulation for use simply during the night.

The rights of a riparian owner under those circumstances seem to be these: in the first place, the bottom principle which I have tried to describe to you is pretty strictly adhered to by the courts,

namely, that a man has the right to the natural flow of the stream, and he is not obliged, for the benefit of anybody lower down the stream, to hold up the water for any part of the twenty-four hours; if he sees fit to use it and let it down. For instance, if a man at the head of the stream, who has got a reservoir, desires to run his mill twenty-four hours a day, a man lower down, who only wants to run his mill ten hours a day, cannot compel the upper proprietor to keep the water up during the night time so that he may have the benefit of it below during the day.

A different question often arises where the mill owners lower down on the stream have businesses which require them to run their mills in the daytime, and those who have mills higher up have businesses which make it desirable for them to run their mills in the night time. Could, then, an upper proprietor hold up the water of the river during the daytime and let it down only at night, when it would not be of any value to those lower down the stream, and not let it down during the hours when the mills downstream find it necessary to do their work? While that question has not been definitely decided anywhere in New England that I know of, the decisions have pointed pretty strongly to the conclusion that that situation is to be governed probably by the established usage of the community. And I take it that that after all means very little more than the advantage of the greater number of persons. If, for instance, there were six or seven privileges on the river, and six of those lower down consisted of mills that wanted to run only during the ten hours of the day, and the one higher up wanted to run only at night, I think the probability is that the court would say he did not have the right to hold up the stream during the ten working hours of the day and let down the water only during the night time; that while he would be permitted to run his mill at night, if he saw fit, he would also be required to let the water down during the daytime.

So it comes pretty much, you see, to the bottom principle, that, subject to the usages which have been made of streams for purposes of water power during the workaday hours of the ordinary man's life, a riparian owner is entitled to have the water of the stream come to him about as nature provided that it should come. He is entitled, however, if he builds a dam, to hold up

the water until he gets a head, provided that that does not mean an extraordinary or unusual limitation of the supply below. This is, perhaps, an instance where the law cannot be exact. If a mill owner should erect his dam and build it at the very driest time in the summer, when the flow in the stream was small, and then undertook to hold up all the water in the stream until he could get a head, so that for a number of days or weeks all those below did not get any, it is exceedingly probable that the courts would say that he had exceeded his rights. But ordinarily, unless such action would result in an unusual reduction of the flow, he is entitled, after he has built his dam, to hold the water up until he has accumulated a head.

Of course the man lower down the stream, while he has not got a right to have those higher up store water for him, does enjoy the advantage which the existence of those reservoirs above him inevitably gives to his site. His case is analogous, for instance, to that of a land owner on a public street. A man who owns the property next to a hotel hasn't any right, as matter of right, to have anybody else maintain buildings or carry on business in that vicinity. Every other owner, if he wants to, can tear his building down and move away and carry on his business somewhere else. But in ascertaining what the value of property on such a street is, the fact that other lots adjoining will, in all probability, for many years be used for business purposes, is one of those things that goes to make his property valuable. So with a mill owner down the stream, the probability that those above him will continue as far ahead as any one can see to take advantage of the power that the stream affords, and use the water and store it in the way that they are accustomed to do, is one of those things which does give, not as matter of right, but as matter of advantage of position, value to the property of the mill owner lowest down.

There is but one way, of course, in which the possessor of riparian rights can be deprived of them, and that is by the exercise of the power of eminent domain, — the power which is given to municipalities or water companies, or exercised by the state when it steps in and takes possession of a stream and undertakes to divert the water flowing in it. And that power can be exer-

cised in two ways. It either can be exercised by the filing of a paper in some registry defining exactly what is taken, when the measure of a man's right to damages is absolutely described by the paper that is filed; or, secondly, the right can be exercised without filing a paper, but simply by the act of diverting the water. The result that follows is apt to be slightly different, according as the right is exercised. If it is exercised by the filing of a paper description, of course the extent to which the water is taken is clearly defined. If it is exercised only by an act, as, for instance, the introduction of a pipe and the diversion of water, the rule is that only so much water is taken as is reasonably necessary for the purposes specified by the legislature in its grant to the town or the water company of the right to take water.

Where, for instance, a town is granted the right by the legislature to take water for a municipal supply from a particular stream, and it is not specified that the town may take the entire supply, the rule is that only so much as will reasonably be necessary for the requirements of the town is to be deemed as taken. That often has an unfortunate result, because no one can tell with any degree of accuracy what the needs of the future will be, and the usual course has been to require the filing of a paper which shall define exactly what is taken. That is far more satisfactory to the man whose land or water is taken, and far safer for the municipality or the company which undertakes to exercise the right.

Now what follows when the rights of a riparian owner are interfered with by a taking? Every act of the legislature which gives that authority must, of course, contain a provision for the payment of damages; otherwise, such legislation would be unconstitutional and void. The usual form of remedy given is that the owner shall be entitled to recover whatever damage he may have suffered, to be estimated either by a jury or by a commission; and the rule which the courts have always adopted is that if his entire property is taken he shall be compensated by paying him in money the fair market value of that property; and if a part of his property only is taken, he shall be entitled to the difference in the fair market value of that property between what it

was worth before the taking and what it is worth after the effects of the taking have been fully felt. "Fair market value," while defined by the courts to mean that price which a willing seller who is not forced to sell should receive from a willing buyer who is not forced to buy, has also been defined by the courts to mean the value as it would be established between two men occupying those positions for the most valuable purposes to which the particular property is adaptable. That, you see, gives to the owner of a water power which may not be developed at all, or which may be only partially, and even unwisely and disadvantageously developed, the right to have considered the most advantageous development of what he has for that purpose for which it may reasonably be adapted, always taking into consideration, of course, if he has an undeveloped or unwisely developed power, what it may cost to completely develop it in the most advantageous way.

To illustrate what I mean: Suppose a man has upon a stream an old-fashioned dam and an old-fashioned water wheel, which is not either accumulating as much storage as might in that place be accumulated, or using what he has got to the best advantage or the most economically. He is not necessarily limited to compensation for the loss of the actual power that is being developed over his wheel under those conditions. He is entitled to have the tribunal that settles that question consider what might be done with his power if it were developed in the most advantageous way, also bearing in mind what it might cost to develop it. And so the man who suffers a loss of only a portion of his power is entitled to have the same consideration taken into account in determining how much the value of that thing which he has has been diminished by what has been taken away.

The same rule applies here as applies in all cases of takings of property, and the element which particularly, I take it, interests engineers, comes into play when a portion of a man's water power has been taken away. If a man owns a piece of real estate, consisting of land and a building, and a railroad or a street is laid out through it so that the land and the building are cut in two, of course one of the obvious things to consider in making up one's mind how much he has been damaged is, how much money will

it cost to put that property back as it was before? In that particular case you never could put it back exactly as it was before, but you could restore the building in whole and the land in part to a condition where it would be useful. So in the case of water power, if a man has a power that develops 100 horse-power, and 50 horse-power is diverted, he still has something left which is worth while, and the question is, How shall he be compensated for the loss of that 50 horse-power? There are various ways of proving that which the courts permit.

In the first place, a crude way which is permitted by the courts is to permit persons who are familiar with the value of water powers in the vicinity — familiar, I mean, with actual sales and leases, if there have been such — to testify what they think as matter of expert opinion the damage done has been. The difficulty with that kind of evidence is that it is very, very difficult to obtain. Hardly any two water powers are alike. It is very rarely that water powers in any vicinity, sufficiently alike, which have been dealt in, can be found, and you rarely if ever find a man who is qualified through actual sales of water power or leases of water power, and who is not an expert engineer, who can furnish you with any assistance upon that line.

In the second place, and obviously it is one of the best ways, the courts now permit the furnishing of evidence as to what it will cost to supply a substitute, and that particularly, I take it, is where your profession furnishes its assistance. Witnesses are permitted to testify what the cost will be of substituting that 50 horse-power which has been taken away, — what it would cost to supply 50 horse-power under those conditions, either by steam or by electricity or by gas or oil, or by any other method that may be thought of or discovered. And while the court always tells the jury, or any tribunal always rules, that that is not final or conclusive upon what damages shall be returned, it is a method by which one can ascertain to a very close degree what the real injury has been which has been suffered.

Now a word with reference to the different kinds of testimony which may be advantageously, and are always advantageously, presented by hydraulic engineers. And first, in that part of the field where nobody questions the propriety of the evidence, and

where there isn't very much room for difference in the testimony, the area of the watershed of course must be a thing that can be ascertained with a great degree of accuracy, and upon which two men cannot vary very much; second, the yield of the watershed is also something that can be ascertained with a very reasonable degree of accuracy. It is true that different places and different conditions afford opportunity for the application, possibly, of different standards, and permit the drawing of different conclusions; but in the main there will not be a very wide divergence among those whose profession makes them expert upon that subject.

It is in the step that follows next that professional men seem to differ most, and where the courts have varied and seemed to vacillate to the largest extent. There often occurs a situation where a power is taken which has never been developed but which it is obvious to everybody possesses advantages for development which are very great and valuable. It is exceedingly probable that nowhere in the vicinity have any similar powers been developed, and yet men who are engaged in that kind of business, men who have built and operated mills and carried on the mill business, and men who have been engaged in your profession, know that that undeveloped power has value, and great value, as a mill site. The suggestion was made to me, Is the value which exists in that undeveloped power at that particular place a subject which is within the province of an hydraulic engineer to give expert testimony upon, and, if it is within his province, will the courts permit it? The courts have permitted it, and again they have excluded it, and it is not by any means certain how such testimony will be dealt with when it next arises. For instance, there was a case tried some ten years ago in the vicinity of Boston where the issue was the value of an undeveloped mill site not far from Boston. It was impossible to obtain testimony from anybody in the immediate vicinity who knew about real estate values and who had had any experience which would qualify him to testify about what that power was worth. It was impossible to obtain an hydraulic engineer who knew anything about real estate values, although he could very well determine the amount of power that could be

developed, and could give a very fair and satisfactory judgment upon what that power might be worth under certain conditions.

Under those conditions which I have stated, our Massachusetts court allowed men who had had experience in building and operating mills such as were adapted to being located in that place to testify what the property was worth as a mill site, including as the subject of their valuation not only the water, but land enough for the buildings, land enough for the dam, and, grouping the two together, the land and the power and the site, to say what that property, that combination, was worth as a mill site. Our court said that the admissibility of that sort of proof was a question which should be left to the discretion of the judge who tried the case; that as a rule of practice it ought to be admitted only where it was really a matter of necessity; in other words, where no other satisfactory evidence could be obtained.

Another case some two years later followed the same rule, and the same evidence was admitted, though our Supreme Court used some strictures with reference to it, and suggested that the discretion of the judge who admitted the evidence had better have been exercised the other way.

In the last case, which was the case of the Lakeside Manufacturing Company *v.* Worcester, the same sort of evidence was offered, at this time from exceedingly competent and experienced hydraulic engineers, and the evidence was excluded, and the Supreme Court commended the exclusion of the evidence. So, while the principle has been established that it is admissible within the discretion of the trial judge, the courts have not exactly smiled upon it.

There does not seem to be any reason in principle, however, why such evidence should not be admitted, and why it is not helpful. It seems to me in the trial of cases of this kind it would be a wiser rule if the courts would open the door a little wider and admit that kind of testimony. I entirely agree that an engineer who undertakes to give value to land in a vicinity of which he has no particular knowledge may very well be led astray, and that his opinion on the value of land does not aid the tribunal very much. But it is not to the land or the value of the land that the expert's attention or evidence is directed under those condi-

tions. It is directed to a thing of potential value, as to which he does have specific and expert knowledge, namely, what can be done with the stream of water flowing there under the conditions which he finds, with the addition of land enough along its bank to place the buildings upon for which the development of power may be useful. It is perfectly idle to say that the ordinary testimony of the ordinary real estate expert can do justice to the claim of the owner of that water power, by attempting to say what its value is in accordance with the standards which he is familiar with; that is, what so-and-so's two acres sold for last year, or what some other man's house and lot brought at such and such a time. Those furnish absolutely no guide as to the value of an undeveloped water power.

Therefore, in answer to that suggestion, I should submit that the wiser plan for our courts to follow, and the wiser course for our engineers to advocate, is the admission in evidence of carefully worked out estimates of the value of a situation, consisting really insignificantly of land and very largely of water and of power, which their particular training gives them an opportunity to know the possibilities of the development of and the value of for practical use.

And, after all, the courts, while exercising most scrupulous care to keep within those lines which the principle I have suggested seems to mark out, have practically made exactly the same thing possible by permitting an engineer, in the first place, to testify to the amount of power that can be developed, which it is plain he can testify to; and, in the second place, to the cost of furnishing an equivalent substitute by steam or other means; and by permitting him, or the lawyer who tries the case, to capitalize that cost and to reduce it to the principal sum. You reach exactly the same result, only by a slightly more roundabout way, and when you reach it by that roundabout way there doesn't seem to the court to be anything that does any particular harm.

For instance, you have a stream flowing down over a fall, and your engineer may testify how much power can be developed by raising the dam to a certain height, and how much it would cost to develop that same amount of power by steam. He may tell how much it will cost per year to develop that same amount of

steam, and the calculation by yourself or the tribunal by which that annual cost can be capitalized is a simple one. The result which you have reached, namely, the capitalized value of the power that is running there down the stream, is just the same as if your engineer had been permitted to testify that that mill site, which from my point of view consists almost wholly of the water power, is worth so much money.

DISCUSSION.

Mr. Leonard Metcalf.* Mr. President and Gentlemen: I think all of you must have been impressed by the beautifully clear and simple way in which Mr. Choate has presented this matter to your attention to-day. It is not as simple as his explanation seems to make it, and I think in other hands you would have a very different feeling about it. I am led to ask Mr. Choate one or two further questions, or to ask him to touch upon one or two further subjects, which I think would be of particular interest to some men present here to-day.

One is the question as to the possibility of compensation in kind. I believe that our courts have not thus far recognized that principle, although it is possible by means of contract or agreement to arrive at a settlement upon such a basis, if it is done in actual advance of the diversion.

The second matter upon which I should be very glad to hear him say a few words is the effect of diverting, for water-works purposes, water which may subsequently be returned to the stream in the form of sewage above the mill privilege which is bringing a suit. I am not certain whether decisions have conflicted on that point, and whether there are any cases in which recognition of that fact have been taken by the court.

Mr. Choate. Mr. President and Mr. Metcalf: In reply to the first question, there isn't any equivalent under the law as it stands at present in which compensation can be made except money, and I do not think that there will be any change made in the law by which any other equivalent will be provided for. Of course one may conceive of cases where the party who has the power to

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take can take in such a way that, while by the exercise of the right upon the one hand it inflicts an injury, it can also, by the exercise of the same right, in a way confer a benefit. I can, perhaps, best illustrate it with reference to another subject, as it occurs to me now. A man owns a large tract of land which really cannot be developed unless a street is laid out through it. The municipality lays a street out through the middle, and it takes so much land, and by the taking of so much land it inflicts an injury, but by the opening up of the tract it confers a benefit which may be equal to or even greater than the injury by the loss of the land which is taken for the street. It is possible that in a way that theory of "set-off," as it were, might be worked out in certain water cases. If the powers of the municipality be broad enough, for instance, to take power with one hand and confer rights upon the owner with the other, which he did not have before, I haven't any doubt that the courts would say that the net result must be the thing for which the owner would alone receive compensation.

It is a little difficult for one to give an illustration of it, but that might be done. A mill owner might, possibly, be deprived of a substantial part of his power, and he might by the same authority which took his power be given a right of way in connection with his mill which would be of very great value to him, but the question would still remain whether he could be obliged to take that substitute in part payment, that is, the right of way or other right or easement which might be selected for him by the authority which took away his water power, — whether he could be required to accept that in lieu of money. I think it would be exceedingly doubtful if one could find conditions where that could be worked out, where a man could be paid in kind.

The second question was, What would be the effect if a municipality took water from a stream above and returned practically the same volume into the stream in the shape of sewage above the privilege? I ask you to look at it for a moment from the mill owner's point of view. In the first place, the mill owner has got a right to say, "I am not only entitled to the volume of water that nature intended to flow in that stream, but I am also entitled to have it come to me as clean as nature intended it to." And

there isn't any question, since the decision in the case of Parker *v.* The American Woolen Company, that a land owner can compel an upper proprietor, who insists upon turning any kind of filth into the stream, to desist, but that he is entitled to have the water come to him as clean as — well, I was going to say, as nature intended it to be; and yet the law is not quite that — as clean as the surrounding conditions and the development of the community will permit. But even that does not give a very good definition of the exact state of the law about it. For instance, if the privilege in question is in the country, and the stream flows through pasture land, and some one undertakes to establish a dye works or bleaching mill on the stream, undoubtedly the lower proprietor would be entitled to have that stream come to him as clean as it used to come from the pastures. But if his privilege was in a city, where more or less minute pollution from all sorts of sources has come from time without mind, until its accumulation has really become serious, he is entitled, rather, to have the stream come to him as it was practically before the new source of pollution was introduced.

I appreciate that that is not a very satisfactory statement of it, and yet I think it is about the way the law stands. Each case has practically got to be governed by its own circumstances, and one has got to study what the conditions were when the particular offensive use sprang up. Take, for instance, a case, of which there exist several in this commonwealth, where cities are turning their sewage, their crude sewage, directly and unfiltered into rivers which furnish powers to privileges below. Would a mill proprietor be justified in saying, "I am entitled to have this stream come to me exactly as it flows ten miles above the city, where it is clean enough to drink?" I think undoubtedly he would not. He would be entitled to have it come to him as it would come through a settled territory like that, where there wasn't any active or intentional pollution, and where the pollution, if such there was, was such as was unavoidable from the existence of a thickly settled population in that place. Now, if the municipality above the mill owner says to the mill owner, "I take out so many thousand gallons of water above your privilege, but I return just as many in the shape of sewage when it comes

to you, so that you really have as much power, no matter what the quality of the water is, as you had before," I think the mill owner is entitled to say, "Not at all. I am not required to take sewage to develop my power; I am entitled to have that stream come to me as nearly as possible" under the conditions that I have described, unaffected by intentional or careless or active pollution; and that his first step would be to stop the introduction of the polluting substance, and then, when he had done that, to get after the municipality as hard as he could for the diminution in the flow of the stream.

Mr. Metcalf. But suppose the community filtered the sewage and returned it to the stream in a purified state?

Mr. Choate. I think that would present a condition which might leave the mill owner without anything to complain of. Of course, I understand it is perfectly practicable to filter sewage so that there is nothing offensive about the water as it is returned, and the situation would then be like that of the upper proprietor who diverts a part of the river and uses it for irrigation and then puts it back again.

Mr. Metcalf. In this connection it may be of interest to refer to a case which occurred in Connecticut, where a water company diverted water for its own uses. The water did return to the watershed through the sewers of the town. Suit was brought, and in response to the water company's plea that the water was returned as sewage, and purified at that, the mill owner urged that the water was returned by the city and not by the water company, and that he was entitled to recover from the water company. He could not recover from the city because the city was not diverting the water. The water company paid the damages.

Mr. Charles W. Sherman.* Mr. President, in attempting to secure a little information on awards for this committee, I ran across a little incident of an attempt at compensation in kind in the reports of the trials of the so-called Sudbury River cases, that is at least interesting. The city of Boston, as most of you know, developed the Sudbury River in 1872, or thereabouts, for a portion of its water supply, and the mill owners below on the Concord River and the Merrimac sued for damages. There was a case in

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Billerica, I think, or somewhere in that neighborhood, where there were perhaps six or eight owners on a single water power privilege, each being entitled to a certain portion of the flow of the stream. While the trial of these cases was in progress, the city, as I understand it, at the instigation of General Butler, who was its chief counsel, purchased the entire right of one of those owners to the flow of the stream. They claimed that the proportion to which this owner was entitled was practically the same proportion of the total flow of the stream at that point as had been diverted by the city, and they offered to deed to each of the remaining owners his *pro rata* share of this part which they had purchased in lieu of the water which they had diverted above; thus, as the statement was made, leaving him in the same condition he was before, as far as the total amount of water which he was entitled to have pass through his mill was concerned. The tribunal threw that offer out. It is a little hard for the layman to see why that should have been so, because it seems as though that was not merely a compensation in kind, as we generally understand it, but an actual returning of what was taken away. Perhaps Mr. Choate can explain it.

Mr. Choate. I don't believe that I can. There are a great many of General Butler's cases which are a little hard to understand.

Mr. Dexter Brackett.* I recall to mind another concrete example bearing upon this question of restitution in kind, going back to the construction of the Cochituate works, when reservoirs were constructed by the city of Boston in order to compensate the mill owners on the Sudbury River below for the water taken from Lake Cochituate. At that time it was decided that compensation could not be made in kind. They offered as compensation the same water, upon the same stream, for the same purpose, yet they were obliged to make compensation in money.

Mr. Richard A. Hale.† Mr. President, I have been very much interested in Mr. Choate's paper, and especially in what he said about twenty-four-hour power. I recall when we were before the New Hampshire legislature asking for a charter for a dam at

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* Chief Engineer, Metropolitan Water Works, Boston.

† Principal Assistant Engineer, Essex Company, Lawrence, Mass.

Reed's Ferry, below Manchester, the counsel for the Manchester companies were insistent that a clause should be put into the charter that no interference should be made with the running of the mills above; that they were accustomed to run ten hours a day, and that they should not be obliged to change their running time. They seemed to be a little afraid that if twenty-four-hour power was developed at this point, the upper mills might be asked to send down the water.

There is one point which I think would be of interest, if Mr. Choate could explain something about it, although it does not occur in this state as much as in the state of New York, and that is with regard to the right of the state to take water for the navigation canals which are being built there. A great many suits are being brought by water-power users on the Oswego and other rivers against the state for diversion of water for use in the canals. These parties are located, usually, on state dams, where the state controls the water, and it looks something like a form of blackmail to bring suit against the state for water power which the state has created. These suits have been brought against the state and there appear to be somewhat peculiar ideas in regard to the rights of the state to use the water for the canals, as against the owners of the water powers. Apparently the only rights which they have arise by prescription through a great many years, and whether the state can take the additional water which is required for the large canals without compensation is a question. A case in which the writer testified for the state has recently been heard before the Court of Claims at Albany, and they have awarded a verdict for the mill owners of about eight per cent. of the amount claimed. This award included land taken as well as water power which was claimed to be taken. Much emphasis was placed by the state on the market value of such powers, and what powers had been bought and sold for in recent years, and evidence was admitted on the value of the power, based on knowledge of market values. Evidence of the cost by steam substitution was also presented. The case is to go to the Court of Appeals in order to settle many legal questions relating to the state's rights in navigable streams. Is there any law relating to that subject which can be stated in a few words?

Mr. Choate. Is this water taken from the Mohawk River?

Mr. Hale. I think some water is diverted from the Mohawk, but this case related to the Oswego River at Fulton.

Mr. Choate. I should suppose that the owner of a privilege, the owner of land on the river, if he owned the land himself and was not simply an occupier of the state's land, would have a right to damages if the water was diverted above him into the canal. Ordinarily one cannot get a right by prescription against the state, and if he had simply settled upon or been permitted to occupy state land, and lost his power because the state had seen fit to use the water for another purpose, I doubt if he could have any remedy at all.

PROGRESS REPORT

OF THE COMMITTEE ON PROPOSED SPECIFICATIONS FOR POST HYDRANTS.

[*Presented January 12, 1910.*]

1. SIZE.

a. The size of hydrants shall be designated by the diameter of the valve opening, which must be at least 5 inches for hydrants having two 2½-inch hose connections and 6 inches for those having three or four 2½-inch hose connections.

In hydrants having valve openings of shapes other than circular, the designation of size must be the diameter of the circle equal in area to that of the valve opening.

b. The net area of the waterway at the smallest part when the hydrant is wide open must not be less than that of the valve opening.

In new designs it is recommended that inside diameter of hydrants be 7 inches and 8 inches respectively for hydrants having 5-inch and 6-inch valve openings.

c. Hydrants must be fitted with bell ends to fit standard pipe, or with flanges of standard dimensions and having standard bolt layouts.

2. GENERAL DESIGN.

a. Any changes in diameter of the water passage through the hydrant must have easy curves and all outlets must have rounded corners of good radius.

b. Hydrants must be so designed that with ordinary usage they will not cause water hammer.

c. Hydrants must be so designed that the leaded joint underground can be strapped.

NOTE. — Further discussion of this report is invited, and may be sent to the Editor

3. MATERIAL OF BODY.

The hydrant body shall be made of cast iron of good quality, such as shall make the metal strong, tough, and of even grain. The strength of the cast iron must be that required by the specifications for cast-iron pipe 12 inches and less in diameter.

4. HOSE NIPPLES AND VALVES.

a. Hose nipples must be of bronze, threaded with a fine thread into the hydrant, and securely pinned in place. Nipples must not be "leaded" into the hydrant.

b. Hose threads on all hydrants to be installed in any given community must of necessity be interchangeable with those already in service, but where practicable threads should conform to the 1906 National Standard, adopted by the National Fire Protection Association.

c. Inside hose-gate valves must have bronze working parts and be of rugged design and must not introduce an unnecessary friction loss. There must be ample clearance between the gate and the hydrant body when the gate is in any position. The gate and parts should be interchangeable and the valves should be located so as to be as accessible as possible for repairs. The gate must be designed so that it cannot come off in use. The top of the stem must be below the level of the hydrant stem nut so that the hydrant wrench can be freely operated. If outside hose-gate valves are used instead of inside valves, they must be of bronze or of iron with bronze trimmings, with nipples cast on the valve body and the valve bolted to the hydrant by two $\frac{3}{4}$-inch tap bolts. The valves must not project further than necessary and must be of the inside screw type, placed in a vertical position with the hand-wheel at least 3 inches below the base of the operating nut.

d. The stems of the hose valves must be $\frac{3}{4}$ of an inch in diameter for the $2\frac{1}{2}$-inch valves, and $\frac{7}{8}$ of an inch in diameter for the valves at the steamer connections.

e. The stem nut of the inside hose-gate valve must be $\frac{3}{4}$ of an inch square.

5. HYDRANT SEAT AND GATE.

a. The seat must be made of bronze, securely fastened in place.

b. The valve must be faced with a yielding material such as rubber or leather, and must be designed so that it can be easily removed for repairs without digging up the hydrant.

c. With gate type of valve, clearance of parts must be such that corrosion will not make the parts inoperative.

6. DRIP VALVE.

a. A positively operating non-corrodible drip valve must be provided and arranged so as to completely drain the hydrant when the main valve is shut.

b. The seat on the drip valve must be securely fastened in the barrel. All other parts of the drip mechanism must be designed to be easily removed through the hydrant top.

7. OPERATING STEM.

a. The operating stem at the base of the thread where threaded, and also where it passes through the stuffing box and gland, must be of bronze not less than 1¼ inches in diameter. The bronze must have a tensile strength of not less than 32 000 pounds per square inch. The remainder of the stem may be of iron with cross-sectional area not less than 1½ square inches, except at couplings, where the area may be 1 square inch. The operating stem must be attached so that in operation it will be impossible for it to become detached.

b. The stem must terminate at the top in a nut of pentagonal shape, finished with slight taper to 1½ inches from point to flat, except for hydrants to be installed where existing hydrants have different shape or size of nut, in which case the additional hydrant must have the same operating nut as the old ones for uniformity. The nut socket in the wrench must be made without taper so as to be reversible.

c. The thread which operates the valve must be Acme standard.

8. STUFFING BOX AND GLAND.

a. The stuffing box and gland must be of bronze or bronze-bushed. If a packing nut is used, it must be of bronze. The bottom of the box and end of the gland or packing nut must be slightly beveled.

b. Gland bolts or studs must be at least $\frac{5}{8}$ of an inch in diameter.

c. Gland bolts or studs must be of bronze, iron, or steel. The nuts must always be of bronze.

9. HYDRANT TOP.

a. The hydrant top must be designed so as to make the hydrant as weatherproof as possible and thus overcome the danger of freezing the stem. Provision must be made for oiling both for lubrication and to prevent corrosion. A reasonably tight fit should be made around stems.

b. There must be cast on the hydrant top, in characters raised $\frac{1}{8}$ of an inch, an arrow at least 4 inches long, and the word "Open" in letters 1 inch high.

10. HOSE CAPS.

a. Hose caps must be provided for all hose outlets, and must be securely chained to the barrel with a welded chain of wire not less than $\frac{1}{8}$ of an inch in diameter.

b. The hose-cap nut must be of the same size and shape as the stem nut.

c. A leather washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed.

11. MARKINGS.

Hydrants must be marked with the name or trade mark of the manufacturer, the nominal size, and the year of manufacture. All letters and figures must be cast on the hydrant well above the ground line. They must be 1 inch high and raised $\frac{1}{8}$ of an inch on the casting.

12. TESTING.

a. Hydrants must be tested to at least 300 pounds per square inch before leaving the factory. If the working pressure is over 150 pounds per square inch, the hydrants must be tested to twice the working pressure. The test should be made with the valve open in order to test the whole barrel for porosity and strength of hydrant body. A second test should be made with the valve shut, in order to test the strength and tightness of the valve.

b. Hydrants must be fully opened and closed before shipping

in order to test the freedom and strength of the parts. The conditions of the test should be made as severe as are liable to occur in service when using a hydrant wrench at least 17 inches long.

13. DIRECTION TO OPEN.

Hydrants must open to the left (counter-clockwise), except those to be installed where existing hydrants open to the right, in which case the additional hydrants must turn the same as the old ones for the sake of uniformity.

H. O. LACOUNT, *Chairman*,
GEORGE A. STACY,
FRANK A. McINNES,
FRED W. GOW,
WILLIAM F. SULLIVAN,
Committee.

DISCUSSION.

MR. H. O. LACOUNT.* Mr. President and Members of the Association: In presenting the report of your committee, it will be proper to give a brief account of the work of the committee since it was appointed. On June 11, 1908, the committee sent letters to the seven manufacturers of fire hydrants who were best known to the committee, asking for data regarding the design and construction of their particular hydrants, with the idea of bringing out their respective practices. There were some ten or fifteen particular points covered in the circular. Although seven manufacturers were written to, only three were heard from.

At the January meeting in 1909, we presented a skeleton of the proposed specifications. It was discussed but little, but it showed that progress was being made. At the time of the New York convention in September, 1909, the specifications were sent to the Secretary in a somewhat more complete form, but at the request of the committee they were not presented to the Association because they were not in final form, and because none of the hydrant committee could be present.

* Engineer and Assistant Secretary, Inspection Department, Associated Factory Mutual Insurance Companies, Boston; Chairman Committee to Prepare Standard Specifications for Fire Hydrants.

On October 13, last, the specifications were put in type, substantially as you now have them before you, and copies were sent to manufacturers, to engineers, to sprinkler companies, and, in fact, to every one whom we had any reason to believe would be especially interested in the subject and could help us. We sent out about 40 circular letters, and in answer to those 40 we heard from only 14, and 3 of the 14 stated that they were not hydrant manufacturers and, therefore, were not directly interested and could make no suggestions.

We improved the opportunity to revise the specifications further, based on the returns from the 11 manufacturers, and on information derived from further investigation by the committee. On November 31 a final draft was sent to the same addresses to whom the previous circular had been sent, 42 concerns in all, and of those 42 concerns we heard from but 12, and 9 of those were represented in the letter from Mr. Wood to the Secretary of this Association which was read at the beginning of to-day's meeting,* no suggestions being offered, however, but merely a request to confer with a committee from the manufacturers.

To go back a little, at the New York convention, the suggestion was made that your committee confer with the standing committee on hydrants of the National Fire Protection Association, in order that the action of the two associations might be in harmony. The chairman of your committee, it so happened, was chairman of the other committee, so it was easy to have a joint meeting, so far as the chairmen were concerned.

On December 31, having now something tangible in hand in the form of the proposed specification in type, your chairman sent copies of the proposed specification, to the 14 members of the National Fire Protection Association's committee and 50 per cent. of the members of that committee responded. The seven replies received were generally favorable to the articles as given in the sheets before you.

Such in brief is the history of the work as it has appeared more or less publicly. The committee have also had several meetings, and I wish to make it very clear that our effort from the start has been to emphasize the fact that the committee's office was

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* See page 224.

open for business all the time, and that we would welcome suggestions from anybody at any time which would help in the work in hand. Although the hydrant manufacturers have finally held a meeting, for which we are very glad, it was too late to be of any service to the committee at this time. They have had opportunities in the past, and no doubt, in view of your action at the opening of this meeting, they will have further opportunities to assist in working out such details as may not be covered in the pamphlet which you have before you or in the amendments which may be made to it. The work of the committee as it has thus far progressed is in your hands in the type-printed copy, and advance copies to a limited number have been distributed among the members. The request of the committee at this time is that the report should be discussed. We do not expect action to-day, and we certainly do not desire it. The committee, moreover, very earnestly desires to secure the ideas and the experience of the entire membership, especially those of you who have had the opportunity of using fire hydrants, and who know about some of the weaknesses as well as about some of the good points of hydrants as they are made to-day. Presumably the manufacturers, through their committee, will get in their hard work a little later, but we are especially desirous of hearing from the water-works people themselves on the subject. The report is before you, Mr. President and gentlemen, and we await your pleasure as to how you wish to take it up.

THE PRESIDENT. Gentlemen, you have heard Mr. Lacount's report on behalf of the committee, and the chair awaits any discussion with regard to it or any motion. Would Mr. Griswold like to say something?

F. M. GRISWOLD, ESQ.* I should like to say, Mr. Chairman, that it would, in my opinion, be very unwise for any one institution to attempt to set up a standard for so extensive a public utility as a fire hydrant. It is something which should be for the whole United States, and even for our neighbors across the line. The United States idea with relation to fire protection and extinguishment is spreading itself with a good deal of power over into the Canadian provinces and across the line into Mexico, and strenuous effort has been made and much hard work has been done to estab-

* General Inspector, the Home Insurance Company, New York.

lish a standard for hose and hydrant couplings. There is nothing which is more intimately associated with the hose coupling for hydrants and the hose which is hitched on to hydrants than the hydrant itself.

My personal opinion in relation to what should be a hydrant is that a hydrant is simply a device in continuation of your service main, and its outlets are those branches which go to serve a district with so much water for consumption; and my idea of the design of a hydrant is to make a hydrant which will let the water come in and let the water go out with the least loss by friction or obstruction in any way to serve what is the requisite standard. The requisite standard of a fire stream is 250 gallons a minute through a $1\frac{1}{8}$ inch smooth nozzle at the end of 100 feet of hose. Now, if we make as a specification on a broad general statement that a hydrant shall be able to deliver and will deliver at least 80 per cent. of the theoretical discharge of water through a thin disk having an orifice equal to the sum of all the hose outlets, on the formula that the discharge equals the square root of $2gh$, we have got a standard for a hydrant, and that standard for a hydrant is how much water can get in and how much water can get out. We don't care about the particular form of the hydrant or the internal organization of it, but what we want the manufacturers to do is to make a hydrant which will deliver a certain amount of water.

Now under these circumstances, gentlemen, I think it would be a very unwise thing for you to go further at this time than to refer this report back to your committee with power to act in conjunction with the other bodies, — the National Fire Protection Association, the American Water Works Association, and the committee of hydrant manufacturers. If we can get a combination of ideas and a combination of consent among these, it will certainly have a great deal more weight and a great deal more influence than would come from even as illustrious an institution as the New England Water Works Association.

This is something which is absolutely country-wide, and takes in our neighbors as well, and we ought to go ahead with it slowly. It isn't a matter which can be worked out in a day or a week or a month, or perhaps in a year, but certainly if we can get together as I have mentioned, this Association, the National Fire Protection

Association, the American Water Works Association, and a committee chosen by the hydrant manufacturers, we can " cuss " and discuss — and probably cuss more than anything else — this proposed specification as it is now written, and we can reach a conclusion by elimination, and then the majority conclusion will be the controlling conclusion and there will be a national standard hydrant for fire service throughout the whole United States and everywhere where hydrants are used to put out fires on this continent. I hope the only action which will be taken now will be to recommit this report; and if you will carry in your minds the necessity of getting water in and getting water out in the proper quantity, you can have right in that statement an absolute guide for a hydrant. There are certain other details which the manufacturers would be glad to take up with a committee from your Association, composed of men not only with technical skill, but with absolute experience added to it, and the National Fire Protection Association would be glad to take a hand in such a consultation, and the American Water Works Association would also be glad to do so. The hydrant people, as a matter of course, would be forced, if they did not do it voluntarily, to come into such a combination with an intent to establish a standard, and I do not doubt for a moment that we could under an arrangement of that kind reach a satisfactory conclusion, and that the manufacturers would provide a device which would deliver the proper quantity of water and let it go in and let it go out with the least loss. I hope the outcome of your consideration of this matter to-day will be neither a rejection nor a criticism of the report at all, as it is not intended that my remarks shall be, but that the report will be referred back to the committee with the idea that they get together with the other interested parties and make a standard which will meet with general broad-minded approval.

The President. Will Mr. Wood say something?

Mr. Wood. No; I don't think I care to say anything.

The President. Mr. Bates?

Mr. Bates. I have nothing to say on this subject.

Mr. George A. Stacy.* I should say, Mr. President, that the suggestion made by Mr. Griswold to go slow has been fully carried

* Superintendent of Water Works, Marlboro, Mass.

out by this committee. I do not think that he can accuse us of trying to rush this thing to a conclusion. The idea in my mind, when this matter was first broached, was to prevent the deterioration of hydrants as they are manufactured. That is, in the competition that the hydrant makers enter into for securing work there is a natural tendency, and perhaps, a proper one, from their standpoint, to clip a little here and a little there in order to be able to give a little closer figure in the market. The result has been in a number of instances to cheapen and to weaken this very important implement; and to prevent that, and also to protect the manufacturer as well, because our interests are mutual, we desire some standard. I don't think anybody would say that the water-works managers or the Association could go ahead without considering the interests of the manufacturers and do justice to this subject. The only way we can reach a conclusion that will be of any value is by working in harmony and being right-minded in the matter, willing to give a little as well as take a little, and accepting the majority judgment as to what is really best according to practical experience and technical knowledge.

Nobody has thought for a moment of laying down any arbitrary rule, and saying we want just this thing and we don't care whether anybody else does or not. And so I think that this idea of getting together and covering the whole country, as the subject itself covers it, as has been brought out, is a good one. I recognize the fact that if the New England Water Works Association, through its committee, can meet with other interests in this matter and come to a satisfactory conclusion as to the principal elements of what should constitute a standard hydrant, we will reach the object which we have aimed at and will confer a benefit upon ourselves and upon water-works people and the community at large throughout the United States. The subject is as broad as that. We certainly are going slowly in this matter. I heartily endorse our chairman's statement, and I think the whole committee is in accord in seeking information in all quarters, technical and practical, as to what is best to be done. I believe that if we earnestly and honestly work in this matter we can evolve a standard hydrant which will be recognized as the best which can be made; and when a manufacturer goes into the market to figure in competition,

he will go in on a level with every other manufacturer. We have always listened to and sought for the experience of others, their advice and criticism, and that is our attitude here to-day. We welcome this broad-mindedness that asks us to take in the whole country, and the New England Water Works Association is big enough to do it.

MR. WILLIAM F. SULLIVAN.* I want, as a member of the Hydrant Committee, to endorse the remarks of Mr. Stacy. I want to say that the chairman of our committee has worked conscientiously on this matter of hydrant specifications, has given a lot of thought to the subject, and has sought in many directions for information. At our meetings he has stated to us the different ways in which he has endeavored to get opinions and suggestions from hydrant manufacturers.

There are other considerations besides "in and out," referred to by Mr. Griswold, which we took into account when we discussed these proposed specifications. For instance, the question of durability of a hydrant, its appearance and size, the tensile strength of the operating stem, a proper seat and valve and a positive waste. For all these details, which practical water-works men know are essential, we tried to suggest something which would be nearly uniform, and at the same time such as are at present furnished by all the principal makers of hydrants.

The committee expected to hear something from the manufacturers before now, and at every meeting we have held the committee have been open to receive suggestions, advice, and criticisms from the hydrant manufacturers. We waited over a year and no advice has been forthcoming. But I see by their communication received to-day that they are now willing to take some action, and I as one member of the committee am entirely willing to have them do so. I did not intend in any way, shape, or manner to ignore or antagonize the hydrant manufacturers, but at this late day, their letter coming before us in the manner that it did, under the impulse of the moment I moved to lay it on the table. My knowing the amount of time and energy that Mr. Lacount has devoted to this work, I thought it was but right and courteous to him and to the committee to present this report to-

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

day, believing that after the report was read, the Association could take action upon it, accept or reject it, recommit it or refer the specifications and the letter from the manufacturers to a new committee. As I did not know what manner of sidetracking was intended for the report, I therefore made the motion.

Mr. George H. Snell.* Mr. President: Personally, I feel that when we talk about standardizing hydrants it is a good deal like a physician prescribing for every patient alike and giving one man the same dose as he would another, without any regard to his constitution or what he requires. That is the way it looks to me. I think there should be a standardization of the nozzles of hydrants, and it seems to me that is about as far as we can conscientiously go. Taking my own town, for instance, the system was installed in 1873, and all hydrants and gates open to the right with a 5-square nut on the hydrant. It would be entirely out of the question for us to change that. That is standardized in itself. We would have to meet those conditions regardless of what the interior of the hydrant might be, or what the make of the hydrant might be. We have several different makes. I am only speaking now of conditions as we find them. We might think of a small town which was going to install a water system, and there might be very little reason to suppose that it would ever grow to any great extent. It ought to be possible for such a town to go into the market and buy a hydrant at a reasonable cost. It seems to me that if we standardize such a thing as a hydrant, each manufacturer has got to make extensive changes in order to conform to it, and that must make it expensive for the consumer. Almost every town has different makes, and it seems to me we should be very careful and consider this matter very thoroughly. I feel that the committee has done a lot of hard work, and if every member of the Association present would express his opinion, I think it would be of great benefit to the committee.

The President. I will state that this report is simply a report of progress. Notwithstanding the committee was appointed in 1907, this is simply a report of progress, and it ought to be discussed very thoroughly, and I hope it will be at some later meeting. As it is merely a report of progress, of course no action upon it is neces-

* Superintendent Water Works, Attleboro, Mass.

sary. The committee will be continued and no doubt will be glad to hear from the hydrant manufacturers and from the members of the Association too. Would Mr. Gould of the Ludlow Valve Company like to say something?

Mr. Gould. I have nothing to say now, Mr. President.

The President. If there is any other representative of the hydrant manufacturers here whom I have not called upon, we will be very glad to hear from him now or at another meeting.

Mr. Charles W. Sherman.* If I can remember back correctly to the time when this committee was appointed, I had the honor of making the motion which led to its appointment. My idea, which is evidently the idea which the committee has followed, was that the standardization should be along the same lines as that of the well-known underwriters' fire pump, — not describing in any way the pattern or details, but simply giving the necessary requirements as to quality of materials, workmanship and capacity, and general items of the kind which should be met in any standard hydrant. This would not in any way hinder the manufacturers from continuing to put out their present standard lines, if they wished to do so and could continue to find a market for them.

As we all know, the makers of fire pumps put out their own standard pumps of all kinds besides the underwriter pump, and the underwriter pumps are of different patterns, although they all fulfill the underwriters' specifications.

I haven't had any experience worth mentioning in operating hydrants, but I have had a little experience in buying them, and it was that really which led me to offer the motion. When we go into the market to order hydrants we usually ask for prices from several makers. We get a series of different prices, but those prices are all based on different hydrants. The hydrants differ in various directions, some excel in one part and some in another; and it would certainly be of great advantage to the purchaser to know that the hydrants, although different in pattern, were on a comparable basis, when deciding where to place his order. Too many times orders have been placed merely on the basis of price, and the results have sometimes been unfortunate.

* Principal Assistant Engineer, with Metcalf & Eddy, Consulting Engineers, Boston.

Mr. Sullivan. About two years ago Mr. Charles L. Newcomb read a paper on fire hydrants* before this Association. In it he showed conclusively that there was a great difference in the efficiency of different makes of hydrants. During the discussion at that meeting, I asked what was a standard 6-inch hydrant. The reason I asked the question was because in my company we have a contract with the city which specifies a standard 6-inch hydrant. No one could tell me at that time what a 6-inch hydrant was, and I do not believe my question can be answered correctly now. Mr. Stacy and others supplemented my remarks, and the result was that this hydrant committee was appointed. When one says a 6-inch hydrant, he may mean a hydrant with a 6-inch valve opening or with a 6-inch barrel or with a 6-inch inlet or with any of these dimensions in combination with any others. The fire commissioners of our city who pass upon hydrant installations look at the size of the barrel. They see it is all right, but they do not know what is down below. It may be a 4-inch valve opening or a 4-inch inlet. I hope this whole subject will appeal to the members and that they will all take an interest in it and help us to get up something which we can all tie to.

Mr. Sherman. It seems to me that the Association should not delay too long the adoption of specifications if other organizations and the manufacturers cannot be brought into line without great delay. It is not a difficult matter to modify or amend specifications even after they have been adopted as a standard, and as we have seen by the letter presented to-day, the possibility of the adoption of such a standard at this meeting has stirred the manufacturers to action, at least to the extent of organizing and appointing a committee upon this matter. I believe in all probability that they will now confer with our committee and that we may expect to get suggestions from them; and I think through the chairman of our committee, who also represents the National Fire Protection Association, and conferences with hydrant makers and other people interested in the subject all over the country, we shall have a broad enough discussion so that we need not hesitate to pass — for the time being, at least — upon specifications when the committee feels ready to present a final report.

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* Vol. XXI, No. 4, p. 378.

Mr. Griswold. May I say one word along that same line. The idea I tried to give you was in the line of expedition. It seems to me that the quickest way to dispose of this matter is to have a committee from each of the interested organizations, not to write letters, but to meet personally and discuss and eliminate differences of opinion and arrive at a conclusion. My idea of expedition would be that the chairman of the committee should call, or practically demand that a representative or representatives, from each of the other organizations should meet his committee and discuss and eliminate the differences and make a standard which would hold water.

Mr. Stacy. I don't know how anybody could have got the idea that the committee wants to determine what shall be the style or the shape of the outside of a hydrant. We don't care to dictate about the general appearance of a hydrant; we are willing to leave that wholly to the artistic ideas of the manufacturers; but we do consider that there are certain essential elements in a hydrant which should be standardized, and that is what we want to arrive at. We are willing to leave to the manufacturers how the hydrant shall look when it is set in the ground.

Mr. M. F. Collins.* I should like to ask if this committee has full power at the present time to meet a committee of the manufacturers for the purpose of discussing this matter.

The President. I think there was a vote passed to that effect.

Mr. Sherman. I don't know about the vote, but it was certainly the intention that the committee should have that power.

The President. Can the Secretary inform Mr. Collins as to whether there was a vote passed giving this committee power to confer with other organizations? I know authority was given them to confer with National Fire Protection Association.

Mr. Kent. I think there was such a vote, although it was not incorporated in the original vote for the appointment of the committee.

Mr. Chase. May I ask, Mr. President, if the discussion on this question is to be closed now, or will the matter come up at the

* Superintendent of Water Works, Lawrence, Mass.

next meeting? It seems to me that the committee has done a great deal of work and it is entitled to the benefit of a full discussion of its report.

THE PRESIDENT. The matter will come up again, certainly, because the report of the committee is only a report of progress, and there will have to be a further report.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 8, 1909.

President Robert J. Thomas in the chair.

The following members and guests were present:

Members.

S. A. Agnew, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, F. D. Barry, J. F. Bigelow, A. E. Blackmer, Dexter Brackett, E. C Brooks, J. C. Chase, J. H. Child, C. E. Childs, H. W. Clark, M. F. Collins, G. K. Crandall, J. W. Crawford, G. E. Crowell, G. W. Cutting, Jr., E. D. Eldridge, J. A. Fitch, J. H. Flynn, A. S. Glover, E. L. Grimes, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, E. A. W. Hammatt, J. C. Hammond, Jr., L. M. Hastings, T. G. Hazard, Jr., D. A. Heffernan, M. F. Hicks, J. L. Howard, F. M. Hutchinson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, E. A. McMillen, C. T. Main, D. E. Makepeace, John Mayo, F. E. Merrill, G. F. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, E. M. Peck, W. A. Peirce, H. E. Perry, Dwight Porter, Henry Roberts, Ransom Rowe, H. W. Sanderson, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, Wm. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, W. H. Vaughn, C. K. Walker, F. B. Wilkins, C. E. Winslow. — 73.

Associates.

Allen & Reed, by Z. M. Jenks; Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond & Co., by F. M. Bates; Builders Iron Foundry Company, by A. B. Coulters; Darling Pump and Manufacturing Company (Limited), by H. H. Davis; Eagle Oil and Supply Company, by John L. Hamilton; George E. Gilchrist Company, by E. H. Ellis, Jr.; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Charles Millar & Sons Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey and F. A. Smith; Pitometer Company, by J. F. Flaherty; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by Fred N. Whitcomb; Union

Water Meter Company, by Frank E. Hall; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins. — 22.

GUESTS.

Messrs. Charles F. Choate, Jr., Arthur P. Stone, F. M. Copeland, Robert S. Dodge, Charles F. Merrill, J. H. Hallowell, James Campbell, Ralph A. Stewart, Boston Mass.; Ernest Johnson, New York City; H. R. Burbeck and C. L. Baker, Abington, Mass.; Samuel F. Compton, East Greenwich, R. I.; J. F. Strub, Marlboro, Mass.; and Mr. Dutcher, Hopedale, Mass. — 14.

Applications for active membership, approved by the Executive Committee, were received from J. Rosenan, Brookline, Mass., and Elliot R. B. Allardice, superintendent of the Wachusett Department of the Metropolitan Water Works. On motion of Mr. Bancroft, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared elected members.

Charles F. Choate, Jr., Esq., of Boston, Mass., spoke on "The Underlying Principles Governing Riparian Water Rights and Diversion Suits." Leonard Metcalf, Charles W. Sherman, Dexter Brackett, and Richard A. Hale participated in the discussion which followed. On motion of Dexter Brackett, a vote of thanks was tendered Mr. Choate for his "very instructive and interesting address."

Mr. Leonard Metcalf, Boston, Mass., presented a report of the committee "to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers Association or other organizations of mill owners leading to the formulation of standard rules and methods of computing or assessing damages for the diversion of water." Messrs. Harold K. Barrows, Richard A. Hale, E. L. Grimes, and Jasper F. Fitch spoke upon matters developed in the report.

Mr. Frank A. Barbour, Boston, Mass., reported for the committee "to gather statistics relating to the depth at which water pipes are laid and the resulting experience with frozen pipes." The discussion which followed was participated in by Messrs. Leonard Metcalf, R. C. P. Coggeshall, George A. Stacy, Charles W. Sherman, and John H. Flynn.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 12, 1910.

The President, Mr. Robert J. Thomas, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, L. M. Bancroft, Roland Barnes, G. W. Batchelder, F. D. Berry, J. F. Bigelow, A. E. Blackmer, J. W. Blackmer, Dexter Brackett, E. C Brooks, G. A. P. Bucknam, James Burnie, J. C. Chase, R. D. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, B. I. Cook, H. R. Cooper, J. W. Crawford, John Doyle, E. R. Dyer, E. D. Eldredge, B. R. Felton, C. R. Felton, J. N. Ferguson, J. H. Flynn, F. F. Forbes, F. L. Fuller, C. W. Gilbert, J. C. Gilbert, A. S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. C. Hersey, Jr., M. F. Hicks, H. G. Holden, J. L. Howard, F. M. Hutchinson, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A King, J. J. Kirkpatrick, H. O. Lacount, E. S. Larned, E. E. Lochridge, A. R. McCallum, F. A. McInnes, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. P. Mason, John Mayo, A. S. Merrill, F. E. Merrill, H. A. Miller, William Naylor, A. S. Negus, R. R. Newman, F. L. Northrop, E. M. Peck, Dwight Porter, W. H. Richards, Henry Roberts, H. E. Royce, G. A. Sanborn, W. H. Sears, E. M. Shedd, J. E. Sheldon, C. W. Sherman G. H. Snell, G. A. Stacy, C. A. Stone, W. F. Sullivan, G. F. Swain, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. L. Thomas, L. D. Thorpe, J. L. Tighe, D. N. Tower, C. H. Tuttle, W. H. Vaughn, C. K. Walker, J. H. Walsh, R. S. Weston, J. C. Whitney, C. E. Winslow, H. B. Wood, I. S. Wood. — 93.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Ashton Valve Company, by C. W. Houghton; Builders Iron Foundry Company, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by H. L. DeWolf; Darling Pump and Manufacturing Company (Limited), by J. L. Hough and H. H. Davis; F. H. Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Pitometer Company, by James F. Flaherty; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Com-

pany, by S. D. Higley and E. M. Shedd; Union Water Meter Company, by F. E. Hall and Edw. F. King; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; Waldo Brothers, by H. E. Browne; Water Works Equipment Company, by W. H. Van Winkle; R. D. Wood & Co., by Walter Wood and Wm. F. Woodburn. — 33.

GUESTS.

John J. Sullivan, Lowell, Mass.; Frank Whitlock, Fostoria, Ohio; F. M. Griswold, New York City; A. C. Lamson, Marlboro, Mass.; E. R. B. Allardice, Clinton, Mass.; J. J. Moore, G. H. Perry, W. O. Teague, R. L. Cary, Edward F. Hughes, Prof. D. C. Jackson, Howard S. Richards, Boston, Mass.; John F. Gleason, Quincy, Mass.; and R. P. M. Lewis, of *Fire and Water Engineering*, New York City. — 14.

The following were elected members of the Association, having been duly approved by the Executive Committee, and one ballot cast for them by the Secretary, in accordance with the vote of the Association on motion of Mr. Frank L. Fuller:

Active. — Lewis R. Dunn, Winthrop, Mass., superintendent Winthrop Water Department; G. A. Sampson, assistant engineer with William Wheeler, Boston, Mass.; Watson Van Winkle, Seattle, Wash., assistant chemist, United States Geological Survey, in charge of investigation of quality and economic value of California waters, and also in charge of investigation of quality of Columbia River waters.

Associate. — Julian d'Este Company, Boston, manufacturer of engineering specialties, pressure regulators for water, steam, etc.

The President read the following letter:

TROY, N. Y., January 10, 1910.

MR. WILLARD KENT, *Secretary*,
New England Water Works Association,
Tremont Temple, Boston, Mass.:

Dear Sir, — The meeting of manufacturers of hydrants, held at the Rensselaer Inn, Troy, N. Y., January 10, 1910, after discussing the specifications on hydrants forwarded to them by your committee, request that a committee of your body be appointed to meet a committee of the hydrant manufacturers to perfect the minor details of construction which such specifications require in order to be complete and full in all its details.

Yours truly,
(Signed) WALTER WOOD, *President*.
JAS. H. CALDWELL, *Secretary*.

There were represented at the meeting: R. D. Wood & Co., Chapman Valve Manufacturing Company, Roe Stephens Valve Manufacturing Company, Darling Pump and Valve Manufacturing Company, Norwood Engineering Company, Eddy Valve Company, Rensselaer Manufacturing Company, The Ludlow Valve Manufacturing Company, Kennedy Valve Manufacturing Company.

Mr. George H. Snell moved that the communication be received and the request complied with. The President suggested that the letter be referred to the Committee on Hydrants, and Mr. Snell then made that motion. Mr. William F. Sullivan thought it would be well to lay the matter on the table until after the report of the Committee on Hydrants had been received, as after the committee had reported it might possibly "go out of business" and some other committee be appointed. Upon the assurance of the President that the present committee would undoubtedly be continued, Mr. Sullivan withdrew his motion to lay on the table. Mr. Snell's motion to refer the matter to the Hydrant Committee was adopted.

A communication was received from Mr. J. P. Beck, general manager of the Cement Products Exhibition Company, calling attention to the Third Annual Cement Show to be held in Chicago, February 18–26, 1910.

Messrs. Richard A. Hale and Lewis M. Bancroft, being a committee appointed by the President, submitted a memorial on Mr. Earle Harvey Gowing, who died November 24, 1909. On motion of Mr. Sherman, it was voted that the memorial be received, placed on record, and published in the Proceedings of the Association.

The retiring President, Mr. Robert J. Thomas, then delivered the following address:

Address of the Retiring President.

Gentlemen, — The New England Water Works Association has added to its history another year of achievement through the labor of its committees, officers and members, in the advancement and exchange of knowledge pertaining to the construction and management of water works. The work of the past year differs but slightly from other years.

In point of membership, a net gain of 19 members during the year is gratifying compared with a small loss the previous year.

Yet in view of the vast number of water-works systems unrepresented in the Association, it obvious that there is still a large field for the expansion of our membership. While it gives us pleasure to note that our society has now reached a total net membership of 715 in good standing, it is to be regretted that 25 members had to be dropped for non-payment of dues and that 12 others saw fit to resign; that is, however, their loss.

The "grim reaper," Death, has been very busy amongst our membership during the year, with the result that eight active and one honorary member have gone from us forever. May the recollection of their good deeds be an inspiration to us. Two of these departed members favored the society with papers during the year. Following the custom I will read the names of the deceased members: J. E. Beals, G. H. Bishop, F. A. W. Davis, I. C. Forbes, E. H. Gowing, A. A. Knudson, C. F. Story, L. F. Rice, and Edwin Reynolds.

Financially, the organization is about in the same sound condition that it was left at the close of last year.

The papers and reports presented at the different meetings during the year cover a wide variety of subjects. At the February meeting, the late Mr. A. A. Knudson read a paper on "Lead-Covered Cables, a Cause of Electrolysis upon Water and Gas Pipe." This paper suggested a new cause of trouble, another source of electrolytic action to be guarded against.

The paper of ex-President Merrill on the "Grounding Electric Light Wires on Water Pipes," also read at this meeting, brought up an important matter for consideration. Officers of the Edison Electric Light Company who were guests of Mr. Merrill discussed the paper from the Electric Company's standpoint. From the water-works side of the question very little was said, probably because the matter is still new and not fully developed.

The Hon. Joseph C. Pelletier, of the Massachusetts Civil Service Commission, addressed the March meeting on the "Civil Service in Its Application to the Water Department." At the same meeting a very valuable and interesting paper on "The Ludlow Filters" was read by the late Carroll F. Story.

At the annual meeting in New York the following papers were presented:

"The Development of the Camaguey (Cuba) Water Works," by Henry A. Young, C. E.; "The Poughkeepsie Water Works," by Dr. John C. Otis; "Disinfection as an Adjunct to Water Purification," by H. W. Clark and Stephen DeM. Gage; "Odors and Tastes in the Water Supply of Holyoke," by James L. Tighe, city engineer, Holyoke, Mass.; "New York City Water Supply," by William W. Brush, C. E.

At the November meeting, Mr. W. S. Johnson gave the meeting a highly interesting treatise on "Ground Waters as Sources of Public Water Supplies."

At the December meeting, Mr. Charles F. Choate, Jr., delivered a most remarkably able and instructive address on "The Underlying Principles Governing Riparian Water Rights and Diversion Suits." This address was followed by the report of the Committee on Water Diversion, etc., an exhaustive and comprehensive statement of facts and figures bearing on the settlement of water damage suits. This report as represented by Mr. Leonard Metcalf, together with the discussion on it, and Mr. Choate's valuable address, will probably make that number of the JOURNAL in which they appear the most valuable we have ever had. Mr. F. A. Barbour also reported at this meeting in behalf of the committee to compile statistics relating to the proper depth at which mains should be laid to prevent freezing. This report was unique inasmuch as it was probably the first attempt to gather and systematize information on this very important branch of water works.

A new committee, headed by Mr. Charles W. Sherman, was appointed to ascertain the custom followed by towns regarding extraordinary extension of mains.

All of the Boston meetings were successful both in attendance and in the program offered. The June meeting was all that could be desired excepting in the essential of attendance. The 121 members and guests who were present, however, had an enjoyable trip on a most delightful day.

At the June meeting the Executive Committee unanimously declined the proposal from the Water Works Manufacturers' Association that they furnish entertainment at our Annual Convention, they to have the control of the distribution of badges and the management of the exhibits. It is feared that our friends in

the supply business who comprise the Water Works Manufacturers' Association did not take very kindly to this action of the Executive Committee, yet they can rest assured that the committee was not actuated by any prejudice towards them, but rather they were animated by the feeling that when their fellow members in the associate class supplied their needs by up-to-date tools, appliances, material, and other supplies of good quality promptly and at a reasonable and fair price that is all they had a right to expect.

The annual meeting, held at the Park Avenue Hotel, New York City, September 8, 9, and 10, was an unqualified success. In point of attendance we have had probably greater numbers at some of our past meetings, but at very few has the number of active members present been surpassed.

Mr. George Batchelder, chairman of the General Committee, and Mr. George Rice, chairman of the Local Committee of Arrangements, and his colleagues, deserve the thanks of the Association for their work, including the entertainment provided at the reception on Tuesday evening, and also on the trip to Ashokan Reservoir, on Friday. This latter event, although during the day on which it took place it rained continuously, I venture to say was most thoroughly enjoyed by those attending, and, despite the rain, there was very little real discomfort. The singing by the engineering staff at the reservoir struck a responsive chord, especially the chorus, "Hold the Dam Waldo, for we are coming." Mr. Fred Whitcomb, who had charge of the exhibits, deserved credit for the successful manner in which he handled that important and instructive feature of the annual meeting.

In order to get a general idea of what a retiring president was expected to talk about in his annual address, I naturally consulted the files of the JOURNAL to see what my predecessors had to say. I found their addresses good reading and contained, as I supposed they would, a review of the work of the Society for the years during which they presided. In addition, I discovered wise recommendations made to the Association; one in particular which struck me very forcibly was repeatedly mentioned: that was the advisability of more general discussion at the meetings, this to be brought about by having copies of all papers sent out in advance to the

members so that those not able to be present at the meeting could send their views in writing. This plan would also allow the reading of many of the papers by their title, thus saving time for topical discussion, which many of the past presidents thought ought to be encouraged. No doubt these recommendations when made were inspired by the hope that the Association would be bettered by their adoption. Certainly they looked for some action in regard to them. When we stop to consider, moreover, that at least some of those past presidents were men whose opinion is entitled to weight, it must seem strange that nothing has come of their suggestions. The advice of one at least of these past presidents is generally considered valuable, and sometimes commands a high price. With the risk of having my humble recommendation also overlooked, I most sincerely urge upon the Association the appointment of a committee of five to consider and report upon the recommendations and suggestions in the annual addresses of our retiring presidents.

Speaking of committees, I wonder if the Association appreciates fully the vast amount of labor and time that some of the committees put into their reports, and how much we are indebted to those members. In saying this, I have in mind the Committee on Water Diversion Matters; and the Committee on the Depth at which Water Mains should be Laid, which reported at the last meeting; also the Committee on Hydrant Specifications, although they have not reported as yet finally. From their preliminary reports we are enabled to judge of the painstaking character of their work.

It gives one pleasure to be able to state that the officers of the Association, from the President down, have performed their duties faithfully and to the best of their ability. I wish to specially commend Miss Ham, the assistant secretary, for the prompt, efficient service rendered by her.

The Executive Committee meetings have been well attended, and the business of the Association has received careful and conscientious consideration at the hands of this committee.

The mayor of Rochester, N. Y., and the president of the Board of Trade sent an invitation to the Association at the annual meeting in New York to have their next meeting at Rochester. It was received too late to come before the New York meeting,

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	702	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 303.31	†4 566.84	‡3 449.57

*Deceased. † Not including December Journal and reprints. ‡ Does not include $1 815 invested in bonds.

but is now in the hands of the Executive Committee, who have full power in the selection of the place for the next annual meeting.

Gentlemen, in closing, I assure you that I am deeply sensible of the courtesy and kindness you have all manifested towards me during my year as President.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of the Secretary.

Mr. President and Members of the New England Water Works Association, — Your Secretary submits the following report of membership, money received, and disbursements approved on account of the New England Water Works Association for the year ending December 31, 1909:

MEMBERSHIP.

The present membership of the Association is 715; that of one year ago was 696, a gain of 19 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows:

MEMBERS.

January 1, 1909.	Total members		633	
	Withdrawals:			
	Resigned	12		
	Died	8		
	Dropped	25	45	588
	Initiations:			
	January	6		
	February	5		
	March	7		
	June	5		
	September	9		
	November	6		
	December	1	39	
	Two members elected in 1908, but qualified in 1909		2	41

	Reinstated:				
	Member dropped in 1906		1		
	Members dropped in 1908		5		
	Members dropped in 1909		10		
	Member resigned in 1908		1		
	Member resigned in 1909		1	18	
					647

HONORARY MEMBERS.

January 1, 1909.	Honorary members		14		
	Died		1		13

ASSOCIATES.

January 1, 1909.	Total associates		49		
	Withdrawals:				
	Resigned	2			
	Dropped	1	3	46	
	Initiations:				
	January	1			
	March	1			
	June	1			
	September	5		8	
	Reinstated:				
	Member dropped in 1909			1	55
January 1, 1910.	Total membership				715

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1909.

RECEIPTS.

Initiation fees			$238.00
Annual dues:			
Members	$1 950.00		
Associates	750.00	$2 700.00	
Fractional dues:			
Members	$24.00		
Associates	32.50	56.50	
Past dues		29.00	2 785.50
Advertisements			1 620.00
Subscriptions			189.00
JOURNALS sold			68.25
Sundries			90.55
June excursion			113.00
Total receipts			$5 104.30

DISBURSEMENTS.

Journal	$1 328.63
Stationery and printing	713.95
Assistant Secretary	600.00
Incidental expenses	328.86
Rent	300.00
Editor	225.00
Secretary	200.00
Advertising agent	171.50
June excursion	150.00
Stenographer	138.75
Reprints	99.35
Music	75.00
Stereopticon	67.70
Treasurer	50.00
Badges	50.00
Library	12.75
Insurance	15.00
Total disbursements	$4 526.49

At present there is due the Association:

For advertisements	$95.00
For Standard Specifications	.10
For index	1.00
For reprints	21.57
Total	$117.67

At present there are outstanding bills against the Association as follows:

Printing, about	$1 000 00
Stenographer	52.50
Rent	100.00
Advertising agent	63.00
Total, about	$1 215.50

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report:

REPORT OF TREASURER.

Lewis M. Bancroft, Treasurer.

In account with the New England Water Works Association.

RECEIPTS.

1909.			
Jan. 6	Balance on hand		$2 711.10
Aug. 1	Dividend, People's Savings Bank, Worcester		67.22
Nov. 1	Coupons, L. S. & Mich. So. R. R. bonds		80.00
Dec. 1	Dividend, Mechanics Savings Bank, Reading		35.30
	Interest on deposits		18.49
Feb. 10	Rec'd of Willard Kent, Sec'y,	$1 771.00	
March 9	,, ,, ,, ,, ,,	805.30	
May 15	,, ,, ,, ,, ,,	789.70	
July 1	,, ,, ,, ,, ,,	113.00	
,, 21	,, ,, ,, ,, ,,	359.00	
Nov. 5	,, ,, ,, ,, ,,	621.95	
1910.			
Jan. 3	,, ,, ,, ,, ,,	644 35	5 104.30
			$8 016.41

EXPENDITURES.

Paid bills, as per itemized statement	$4 566.84
BALANCE ON HAND.	
Deposit, People's Savings Bank, Worcester	1 731.86
,, Mechanics Savings Bank, Reading	1 035 30
,, First National Bank, Reading	45.38
,, Liberty Trust Co., Boston	637.03
	$8 016.41

ASSETS AND LIABILITIES.

ASSETS.

Cash balance in banks	$3 449.57
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R., 4%, due May 1, 1931. Book value, $1 815.00. Market value	1 900.00
	$5 349.57

LIABILITIES.

Bill due for Library search	$3.20
Net assets	5 346.37
	$5 349.57

Approved as correct, January 7, 1910.

GEORGE CASSELL,
JOHN C. CHASE, } *Auditing Committee.*

Reading, Mass., January 6, 1910.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1909.		
February 10	Robert J. Thomas, advertising agent to January 1, 1909	$62.00
	L. M. Bancroft & Son, bond	15.00
	Thomas P. Taylor, stereopticon	10.00
	American Society of Civil Engineers, binding . . .	4.00
	Miss J. M. Ham, salary for January	50.00
	W. N. Hughes, envelopes and printing	65.00
	The Brunswick, music, January meeting	15.00
	D. Gillies' Sons, printing	63.98
March 11	The Brunswick, music, February meeting	15.00
	W. N. Hughes, binding and printing	32.50
	Miss J. M. Ham, salary for February	50.00
	Remington Typewriter Company, overhauling machine	16.74
	D. Gillies' Sons, printing	4.50
	Boston Society of Civil Engineers, rent to February 28	100.00
27	Miss J. M. Ham, salary for March	50.00
April 1	W. N. Hughes, printing	3.75
	Thomas P. Taylor, stereopticon	20.00
	Hub Engraving Company, plates	24.90
	The Brunswick, music, March meeting	15.00
	Willard Kent, salary to March 31	50.00
	Willard Kent, expenses to March 31	58.85
10	Charles W. Sherman, advertising agent to April 1 .	58.75
	Bacon & Burpee, report of January, February, and March meetings	58.75
	Richard K. Hale, salary to April 1	75.00
	Richard K. Hale, postage and expenses	9.60
May 1	American Society of Civil Engineers, library search .	18.45
	Miss J. M. Ham, salary for April	50.00
19	Samuel Usher, printing March JOURNAL and reprints.	455.72
	Hub Engraving Company, plates	4.89
	Suffolk Engraving and Electrotyping Company, plates	5.47
28	W. N. Hughes, printing	3.00
	The Mudge Press, printing	5.50
	Miss J. M. Ham, salary for May	50.00
June 15	D. Gillies' Sons, printing	5.75
	Boston Society of Civil Engineers, rent to May 31 .	100.00
30	Henry A. Wheeler & Co., burgee	10.00
	Amount carried forward	$1 637.10

	Amount brought forward	$1 637.10
June 30	W. N. Hughes, printing	2.00
	Steamer *King Philip*, June meeting	150.00
	Miss J. M. Ham, salary for June	50.00
July 8	Samuel Usher, printing	173.00
17	Willard Kent, salary to July 1	50.00
	Willard Kent, expenses to July 1	10.00
	Charles W. Sherman, advertising agent	57.50
23	Miss J. M. Ham, salary for July	50.00
	Miss J. M. Ham, expenses	45.37
	Richard K. Hale, salary to July 1	75.00
	Richard K. Hale, expenses	11.00
27	Geo. W. Batchelder, expenses annual convention	19.70
August 12	Samuel Usher, Standard Specifications	27.50
	Suffolk Engraving Company, plates	7.87
	Wm. E. Whittaker, drafting	1.00
September 6	W. N. Hughes, envelopes and printing	48.00
	D. Gillies' Sons, printing	10.50
	Miss J. M. Ham, salary for August	50.00
13	W. N. Hughes, printing	15.50
	Boston Badge Company, badges	50.00
	Samuel Usher, June JOURNAL and reprints	335.50
16	Fred P. Chase, wreath, Jos. E. Beals' funeral	10.00
20	Thomas P. Taylor, stereopticon, N. Y. convention,	37.70
October 18	Suffolk Engraving and Electrotyping Company, plates	2.24
	Miss J. M. Ham, salary for September	50.00
	Willard Kent, salary to October 1	50.00
	Willard Kent, expenses	10.00
November 6	Boston Society of Civil Engineers, rent to August 31,	100.00
	Bacon & Burpee, report of twenty-eighth annual convention	80.00
	Samuel Usher, printing	35.00
	Miss J. M. Ham, salary for October	50.00
	Miss J. M. Ham, expenses	81.54
	Wm. E. Whittaker, making drawing	3.50
	W. N. Hughes, printing	33.75
25	D. Gillies' Sons, printing	38.75
	The Brunswick, music, November meeting	15.00
	W. N. Hughes, printing postal cards and envelopes,	63.00
	Miss J. M. Ham, salary for November	50.00
27	Charles W. Sherman, advertising agent	55.25
December 11	Suffolk Engraving and Electrotyping Company, plates	48.79
	Amount carried forward	$3 691.06

	Amount brought forward	$3 691.06
December 11	Richard K. Hale, salary to October 1, 1909	75.00
	Richard K. Hale, expenses	7.60
	D. Gillies' Sons, printing	7.75
	L. M. Bancroft, salary to December 31, 1909	50.00
	The Brunswick, music, December meeting	15.00
1910.		
January 6	Samuel Usher, September JOURNAL and reprints	504.50
	Suffolk Engraving and Electrotyping Company, plates	33.60
	Albert S. Glover, telephone service	17.22
	Walter L. Beals, dues retained, L. P. Thomas	7.00
	Miss J. M. Ham, salary for December	50.00
	Miss J. M. Ham, sundry expenses	17.86
	Willard Kent, salary to December 31, 1909	50.00
	Willard Kent, sundry expenses	40.25
		$4 566.84

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 12, 1910.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1909.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1909, and which are consequently not included in the Secretary's and Treasurer's statements); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat smaller in total pages and pages of text than that of several preceding years.

Illustrations. — The total cost of illustrations for the year, including printing, has been $227.77, or 7.3 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge, and additional reprints, when desired, at the cost of the paper and press work. Advance copies of four of the papers presented during the year have also been printed, three of which have not yet appeared in the Journal. The net cost to the Association for reprints and advance copies has been $131.35 (assuming that the December reprints chargeable to members are promptly paid for).

Circulation. — The present circulation of the Journal is:

Members, all grades	715
Subscribers	62
Exchanges	25
Total	802

an increase of 22 over the preceding year.

Advertisements. — The December issue contained 23½ pages of paid advertising, which, if maintained throughout the year, would mean an annual income from this source of $1 640. A year ago the figures were 25½ pages and $1 760, showing considerable decrease during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $57.20 have been sold. Five hundred copies have been printed, at a cost of $27.50, representing a net gain of $29.70 for the year. The net gain up to a year ago had been $161.50, so that the total net gain from this source to date is $191.20. There are still about one hundred and forty-eight copies of specifications on hand, or about $14.80 worth if sold at retail.

The Association has a credit of $5.05 at the Boston Post-office, being the balance of the money deposited for payment of postage upon the Journal at

pound rates. I know of no outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXIII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1909.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	105	39	144	–	27	4	5	180	—
2	June	78	6	84	–	27	4	7	122	13
3	September	128	14	142	–	27	4	8	181	9
4	December	77	12	89	7	27	4	17	144	6
	Total	388	71	459	7	108	16	37	627	28

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXIII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1909.

RECEIPTS.		EXPENDITURES.	
From advertisements . .	$2 060.00	For printing JOURNAL . .	$2 044.09
From sale of JOURNALS .	69.25	For preparing illustrations,	132.26
From sale of reprints . .	32.92	For editor's salary	300.00
From sale of cuts	6.00	For editor's incidentals .	35.20
Subscriptions	192.00	For advertising agent's commissions	227.50
	$2 360.17	For reporting	191.25
Net cost of JOURNAL . . .	750.98	For reprints	131.35
		For advance copies . . .	49.50
	$3 111.15	Gross cost of JOURNAL . .	$3 111.15

TABLE No. 3.

Comparison between Volumes XV to XXIII, Inclusive, Journal of the New England Water Works Association.

	4 Numbers of Vol. XV. 1900–1901.	Vol. XVI. 1902.	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.
Average edition (copies printed),	1 200	1 200	1 200	900	900	900	1 085	1 000	1 000
Average membership	586	571	587	596	625	665	693	699	710
Circulation at end of year . . .	617*	648*	656*	667	705	767	785	780	802
Pages of text	363	403	430	491	587	495	500	500	459
Pages of text per 1 000 members	618	707	733	824	939	745	722	715	646
Total pages, all kinds	536	584	619	794	784	662	669	681	627
Total pages per 1 000 members .	913	1 020	1 051	1 332	1 254	995	964	976	884
Gross Cost:									
Total	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15
Per page	4.10	4.18	4.38	3.69	4.17	3.88	3.95	4.01	4.97
Per member	3.75	4.27	4.61	4.91	5.23	3.87	3.82	3.91	4.39
Per member per 1 000 pages .	6.99	7.32	7.46	6.18	6.67	5.85	5.70	5.88	7.00
Per member per 1 000 pp. text	10.13	10.60	10.72	10.00	8.91	7.81	7.62	8.02	9.56
Net Cost:									
Total	$332.90	$622.89	$770.62	$618.11	$1 072.95	$387.96	$483.15	$131.06	$750.98
Per page	.62	1.07	1.25	.82	1.37	.58	.72	.19	1.21
Per member	.57	1.09	1.31	1.09	1.72	.58	.70	.19	1.07
Per member per 1 000 pages .	1.06	1.87	2.12	1.30	2.20	.88	1.04	.28	1.70
Per member per 1 000 pp. text	1.57	2.71	3.05	2.22	2.93	1.18	1.39	.39	2.33

* Exclusive of three hundred sample copies.

Mr. George Cassell, Chairman of Auditing Committee, submitted the following report:

Report of Auditing Committee.

January 7, 1910.

We herewith certify that we have examined the books and accounts of the Secretary and Treasurer of the New England Water Works Association and find same correctly kept, with the several disbursements supported by proper vouchers duly approved.

We are pleased to report that the assets of the Association have increased seven hundred and seventy-seven dollars and twenty-seven cents ($777.27) during the year.

Respectfully submitted,

GEORGE CASSELL,
JOHN C. CHASE,
Auditing Committee.

On motion of Mr. Charles W. Sherman, it was voted that the reports of the several officers be accepted, placed on file, and published in the Journal.

The first paper of the afternoon was by Marshall O. Leighton, chief hydrographer, United States Geological Survey, Washington, D. C., on "Governmental Policy in Relation to Water Powers." The paper was discussed by Prof. Dugald C. Jackson, Prof. George F. Swain, and Prof. Dwight Porter.

Dr. William P. Mason, professor of chemistry, Rensselaer Polytechnic Institute, Troy, N. Y., spoke on "The Maidstone Typhoid Epidemic." Mr. Robert S. Weston spoke briefly in regard to Ground Water Supplies.

Mr. H. O. Lacount, chairman, submitted a report for the committee to prepare a standard specification for fire hydrants. The matter was discussed by Mr. F. M. Griswold, Mr. George A. Stacy, Mr. William F. Sullivan, Mr. George H. Snell, and Mr. Charles W. Sherman. The report was received as a report of progress, and the committee continued.

Election of Oficers.

Mr. J. W. Crawford, in behalf of the tellers appointed to canvass ballots for officers for the ensuing year, submitted the following report.

Whole number of ballots	252
Blank	6
Imperfect	4

For President.

George A. King	240
Allen Hazen	1
N. M. Baker	1

For Vice-Presidents.

Allen Hazen	240
Ermon M. Peck	237
Michael F. Collins	237
Leonard Metcalf	239
Irving S. Wood	236
Frank A. McInnes	238
W. W. Clark	1
Charles R. Bettes	1
R. C. P. Coggeshall	1

For Secretary.

Willard Kent	240

For Treasurer.

Lewis M. Bancroft	239

For Editor.

Richard K. Hale	241

For Advertising Agent.

Robert J. Thomas	239

For Additional Members of Executive Committee.

George A. Stacy	238
George W. Batchelder	238
Edwin C. Brooks	238

For Finance Committee.

John C. Chase	238
George H. Finneran	237
Albert L. Sawyer	237

Respectfully submitted,

JOHN W. CRAWFORD.
GEORGE A. P. BUCKMAN.

The President declared the officers elected and presented Mr. King, the new President, who said: "I desire to express my thanks for the great honor you have done me, and I pledge to do

all in my power to serve you in the coming year. I trust that you will overlook all my shortcomings."

On motion of Mr. M. F. Collins, a vote of thanks was tendered the retiring President, Mr. Thomas, "for the very able manner in which he has conducted the business of the Association during the past year."

Adjourned.

Financial Analysis of Treasurer's Annual Report.

RECEIPTS.

Cash on hand January 6, 1909				$2 711.10
Dividends, coupons, and interest				201.01
Initiation fees:				
Members previous to 1909	$6.00			
During 1909	152.00			
		$158.00		
Associate members, 1909		80.00		
Total initiation fees			$238.00	
Annual dues:				
Members previous to 1909	$29.00			
During 1909	1 971.00			
For 1910	3.00			
		$2,003.00		
Associate members, 1909		782.50		
Total annual dues			2 785.50	
Total received from members				3 023.50
JOURNAL, 1909:				
Advertisements	$1 620.00			
Subscriptions	189.00			
Sale of JOURNALS	68.25			
Sale cuts and reprints	9.60			
		$1 886.85		
JOURNAL, previous to 1909		19.80		
Total received from JOURNAL				1 906.65
Miscellaneous receipts, 1909:				
June excursion	$113.00			
Sale of pipe specifications	56.40			
Sale of Buttons	3.75			
Sale of Index	1.00			
Total miscellaneous receipts				174.15
Total receipts				$8 016.41

EXPENDITURES.

JOURNAL:			
Advertising agent, commission, 1908	$62.00		
1909	171.50		
		$233.50	
Plates		132.26	
Printing		1 334.47	
Editor, salary		225.00	
Expense		28.20	
Reporting		138.75	
			$2 092.18
Office:			
Secretary, salary		$200.00	
Expense		119.10	
Assistant Secretary, salary		600.00	
Expense		144.77	
Rent, 1908	$133.33		
1909	166.67		
		300.00	
Telephone toll charges		17.22	
Typewriter repairs		16.74	
Membership list		173.00	
Library		9.00	
Stationery		68.98	
Miscellaneous printing		19.00	
			1 667.81
Meetings and Committees:			
Stereopticon		$67.70	
Music		75.00	
June excursion		152.00	
Badges		50.00	
Burgee		10.00	
Circulars		169.45	
Envelopes		154.75	
Library research		18.45	
			697.35
Treasurer's salary and bond			65.00
Pipe specifications			27.50
Miscellaneous expenses			17.00
Total expense			$4 566.84

Assets and Liabilities.

ASSETS.

Cash in banks			$3 449.57
Bonds, market value			1 900.00
Accounts receivable:			
Initiation fees	$11.00		
Annual dues	7.00		
		$18.00	
JOURNAL:			
Advertising	$440.00		
Subscriptions	3.00		
Sale of JOURNAL	1.00		
Sale cuts and reprints	29.32		
		473.32	
Total accounts receivable			491.32
Postage deposit			5.05
Total assets			$5 845.91

LIABILITIES.

Accounts payable:	
Advertising agent's commissions	$56.00
Editor, salary	75.00
Expense	7.00
Printing December JOURNAL	854.97
December reprints	35.50
Reporting	52.50
Rent	133.33
Circulars	18.50
Library research	3.20
Total account payable	$1 236.00
Surplus	4 609.94
	$5 845.94

February Meeting.

Hotel Brunswick,
Boston, February 9, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Members.

C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, F. D. Berry, A. E. Blackmer, J. W. Blackmer, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, J. C. Chase, C. E. Childs, R. C. P. Coggeshall, M. F. Collins, F. W. Dean, J. C. DeMello, Jr., A. O. Doane, E. R. Dyer, E. D. Eldredge, F. F. Forbes, F. J. Gifford, A. S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, Allen Hazen, M. F. Hicks, F. S. Hollis, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, F. C. Kimball, G. A. Kimball, G. A. King, Emil Kuichling, E. E. Lochridge, F. A. McInnes, S. H. McKenzie, N. A. McMillen, D. E. Makepeace, W. E. Maybury, John Mayo, G. F. Merrill, Leonard Metcalf, William Naylor, A. S. Negus, F. L. Northrup, O. E. Parks, E. M. Peck, T. A. Peirce, H. E. Royce, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, W. E. Smith, G. H. Snell, G. A. Stacy, J. T. Stevens, W. F. Sullivan, L. A. Taylor, H. L. Thomas, W. H. Thomas, W. H. Vaughn, E. S. Tucker, C. K. Walker, L. R. Washburn, R. S. Weston, Elbert Wheeler, G. E. Winslow, I. S. Wood. — 75.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by H. L. DeWolf; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; F. H. Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Lead-Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pitometer Company, by James F. Flaherty; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Meter Company, by Frank E. Hall; United States Cast-Iron Pipe and Foundry Company, by F. W. Nevins; Waldo Bros., by James G. Lincoln; R. D. Wood & Co., by W. F. Woodburn. — 25.

Guests.

S. D. Soule, superintendent, Gardiner, Me.; F. W. Dinwiddie, Gardner, Mass.; H. B. Eldredge, Jr., and M. Craven, East Greenwich, R. I.; Z. R. Forbes, water registrar, Brookline, Mass.; Samuel C. Prescott, Boston; J. F. Barry, Westfield, Mass., and Everett S. Locke, water registrar, Lexington, Mass.; Harvey S. Chase, Boston. — 9.

Applications for membership, properly endorsed and approved by the Executive Committee, were presented by the Secretary from the following: Albert H. Wehr, Baltimore, Md., vice-president and general manager of the Baltimore County Water and Electric Company; A. E. Walden, Baltimore, Md., superintendent and chief engineer of the Baltimore County Water and Electric Company; Gordon Peacock, Jr., Centerville, Ia., superintendent of Centerville Water Works; Philip Arthur Potter, New York City, engaged in electrolytic and water-works investigations, meter testing and water-works construction; Wilson F. Monfort, St. Louis, Mo., consulting chemist in water-works problems; John J. Moore, Hingham, Mass., engaged in laying out and building water works; Elbert C. Aldrich, Auburn, N. Y., city engineer; Walter C. Hopper, Paterson, N. J., superintendent Acquacknonk Water Company.

The Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared duly elected members of the Association.

The President announced that the first business in order was the consideration of the following proposed amendments to the Constitution:

Amend Section 3, Article II, by adding:

"*Provided, however,* that Honorary Members elected from the members of the Association shall not thereby lose the right to vote and to hold office."

Amend Section 5, Article III, by striking out the word "ten" and inserting in place thereof the word "four," so as to read as follows:

Section 5. The annual membership dues shall be payable in advance on the date of the annual meeting in January. At the expiration of four months after the annual meeting, the Secretary shall notify each member who has not paid his dues for the current year that unless the same are paid within thirty days his membership in the Association shall cease; and if said dues are not paid within said period, the Secretary shall drop the name of said member

from the membership roll. The Executive Committee may, however, at its discretion reinstate said person on the payment of all arrears.

Amend Section 3, Article VI, in third line by striking out the word "quarterly" and inserting the word "monthly," so that it shall read as follows:

SECTION 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer monthly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association, and especially of changes in the membership.

THE PRESIDENT. I will call on Mr. Sherman to state the reasons for the proposed changes.

MR. CHARLES W. SHERMAN.* Mr. President: The first amendment, which suggests that honorary members who have been elected from the regular membership of the Association shall not thereby lose the right to vote and to hold office, is merely to formally legalize the practice which the Association adopted some years ago when it elected Professor Sedgwick as president. He, like several others of our honorary members, had been an active member of the Association for many years, and it would seem in many ways an injustice that such persons should lose the right to vote and to hold office, and it never was the intention, I am sure, when the original constitution was adopted, that they should do so. The Association has assumed that to be the case in electing Professor Sedgwick to its presidency while he was an honorary member, but it seemed best, in order that there should be no question in the future about this, to introduce this amendment and make it a sure thing, so far as the constitution is concerned.

The second amendment, requiring that members shall pay their dues within four months, or else be subject to suspension within a further period of a month, has been suggested because the present method of allowing them ten months in which to pay has resulted in many members, through carelessness or otherwise, laying their notices aside and forgetting all about the matter for nearly the whole year, and then, when they do get their final notice, the returns often do not get in before the end of the year. The Secretary has no discretion, but must drop these members from the roll.

* Principal Asst. Engineer, with Metcalf & Eddy, Consulting Engineers, Boston, Mass.

and it results in reporting at the annual meeting a number of members dropped for non-payment of dues who haven't any intention of getting dropped, as is evidenced by the fact that most of them get reinstated within a month after the beginning of the new year. It is better business in every way that the money should be collected more promptly, it will be no hardship on the members, and it will also result in allowing time enough for reinstatement of members who have carelessly allowed themselves to get suspended, and have the membership roll cleared at the time of the annual meeting.

In regard to the third amendment, it has been the practice of the Secretary, I believe, to transmit funds to the Treasurer nine or ten times a year, depending on the amount of collections. Often the collections would be so great within the quarterly period that they would constitute a much larger sum than the Secretary would care to carry in his hands, while, on the other hand, if such a sum were held back, it might be a serious embarrassment to the Treasurer in paying the bills incurred by the Association. Consequently, it has seemed best to make a constitutional provision that the amounts received by the Secretary should be turned over monthly.

Mr. R. C. P. Coggeshall.* I was one who had a good deal to do with the framing of the constitution, and I can say that I never was more surprised in my life than when I found out that under its provisions honorary members were possibly deprived of the right of voting. I always supposed that they had that privilege, and it certainly was the intention at the time the constitution was framed that they should not be deprived of it.

The President thereupon put the question on the adoption of the several amendments proposed, and each was adopted by more than a two-thirds vote.

The first paper upon the program for the afternoon was "Depreciation in Water Works Accounts, with Reference to Uniform Reports," by Harvey S. Chase, Esq., certified public accountant, Boston. It was discussed by Gen. Elbert Wheeler, Mr. Allen Hazen, Mr. George A. Kimball, Mr. Charles W. Sherman, Mr. Francis W. Dean, Mr. Frank C. Kimball, Mr. Leonard Metcalf,

* Superintendent of Water Works, New Bedford, Mass.

Mr. Samuel H. McKenzie, Mr. Edwin C. Brooks, Mr. George A. Stacy, and Mr. R. C. P. Coggeshall.

Mr. A. O. Doane, division engineer, Metropolitan Water and Sewerage Board, Boston, read a paper on "The Purchase of Coal on Efficiency Basis." The subject was discussed by Mr. Harry L. Thomas, Mr. A. S. Negus, Mr. Francis W. Dean, Prof. Frederick S. Hollis, and Mr. Edward D. Eldredge.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Boston, Mass., December 8, 1909.

Present: President Robert J. Thomas, and members George A. King, George A. Stacy, Ermon M. Peck, George W. Batchelder, L. M. Bancroft, Richard K. Hale, Charles W. Sherman, William F. Sullivan, and Willard Kent.

Applications for membership were received as follows: Elliot R. B. Allardice, superintendent Wachusett Department of Metropolitan Water Works, Clinton, Mass.; and M. J. Rosenau, Department of Preventive Medicine, Harvard Medical School, 82 Stedman Street, Brookline, Mass.

Voted: That above-named applicants be recommended to the Association for membership.

Voted: On motion of Mr. Sherman, that it be recommended to the Association that Article II, Section 3, of the Constitution be amended as follows: By adding at the end thereof the words, "Provided, however, that Honorary Members elected from the Members of the Association shall not thereby lose the right to vote and to hold office," so as to read as follows:

Section 3. Members only shall be eligible to office and entitled to the right to vote, provided, however, that Honorary Members elected from the Members of the Association shall not thereby lose the right to vote and to hold office.

Voted: On motion of Mr. Sherman that it be recommended to the Association that Article III, Section 5, of the Constitution be amended by striking out the word "ten" and inserting in place thereof the word "four," so as to read as follows:

Section 5. The annual membership dues shall be payable in advance on the date of the annual meeting in January. At the expiration of four months after the annual meeting the Secretary shall notify each member who has not paid his dues for the current

year that unless the same are paid within thirty days his membership in the Association shall cease; and if said dues are not paid within said period, the Secretary shall drop the name of said member from the membership roll. The Executive Committee may, however, at its discretion, reinstate said person on the payment of all arrears.

Place of holding next annual convention was discussed and the Secretary instructed to correspond with the city of Rochester, N. Y., in relation thereto.

Voted: That the President appoint a committee of seven to take action relative to increasing the membership of the Association.

Voted: On motion of Mr King, "that a meeting of the Association be held in the city of Hartford, Conn., on the second Wednesday of April next."

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Boston, Mass., January 12, 1910.

Present: President Robert J. Thomas, and members L. M. Bancroft, Charles W. Sherman, William F. Sullivan, Richard K. Hale, George W. Batchelder, Ermon M. Peck, George A. King, George A. Stacy, and Willard Kent.

Applications were received from Lewis R. Dunn, superintendent Water Department, Winthrop, Mass.; George A. Sampson, civil engineer, Cambridge, Mass.; and Walton Van Winkle, chemist, Seattle, Wash., for membership; and from Julian d'Este Company, manufacturers of engineering specialties, Boston, Mass., for associate membership.

All were by vote recommended for admission.

Fifteen delinquents having paid their dues were by vote re-instated to membership.

Voted: That it be recommended that Article VI, Section 3, of the Constitution be amended by striking out the word "quarterly" in the third line and inserting the word "monthly," so that it shall read:

Section 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer monthly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association and especially of changes in the membership.

Voted: That proposed changes in By-Laws appear with the notice of the next regular meeting.

Voted: That the annual convention of this Association for 1910 be held at Rochester, N. Y.

Adjourned.

Willard Kent, *Secretary.*

Wednesday, January 12, 1910, 5 p.m.

A meeting of the Executive Committee of the New England Water Works Association was held at the Brunswick Hotel immediately after the annual meeting.

Present: President George A. King, and members Lewis M. Bancroft, Michael L. Collins, Richard K. Hale, Willard Kent, Frank A. McInnes, Ermon M. Peck, George A. Stacy, Robert J. Thomas, and Irving S. Wood.

Voted: To hold the June outing in Providence, R. I. The President appointed the following committee of arrangements to serve with him: I. S. Wood, A. B. Lisle, and F. N. Connet.

The President was authorized to appoint a committee to consider the advisability of incorporating the Association. The following were appointed to serve with the President: Messrs. Leonard Metcalf and Frank A. McInnes.

The President was authorized to appoint a committee to arrange for the special meeting in Hartford, Conn., on April 13. The following were appointed: Messrs. Ermon M. Peck, Henry Roberts, Fred D. Berry, A. E. Martin, John H. Walsh, and W. E. Johnson.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, February 9, 1910.

Present: President George A. King, and members Allen Hazen, Ermon M. Peck, Michael F. Collins, Leonard Metcalf, Irving S. Wood, Frank A. McInnes, George A. Stacy, George W. Batchelder, Edwin C. Brooks, Lewis M. Bancroft, Richard K. Hale, and Willard Kent.

Eight applications were received and the applicants were by unanimous vote recommended for membership, viz.,

Albert H. Wehrn, vice-president and general manager, Baltimore County Water and Electric Company, Baltimore, Md.; A. E. Walden, superintendent and engineer, Baltimore County Water and Electric Company, Baltimore, Md.; Gordon Peacock, Jr., superintendent Centerville Water Works, Centerville, Ia.; Philip Arthur Potter, water-works investigations and construction, New York City; Wilson F. Monfort, consulting chemist in water-works problems, St. Louis, Mo.; J. J. Moore, water-works construction, Hingham, Mass.; Elbert C. Aldrich, city engineer, Auburn, N. Y.; Walter C. Hopper, superintendent Acquackanock Water Company, Passaic, N. J.

Voted: That the President be and hereby is authorized to appoint a committee with full powers to make arrangements for the Annual Convention of 1910.

The President was by vote made a committee to attend one meeting of the organization of "Boston, 1915."

The committees on the April and June meetings reported progress, and their arrangements as outlined were endorsed by vote.

Mr. Metcalf, of the Committee on Incorporation, reported, recommending that no action be taken at the present time, and his report was by vote accepted and the recommendation adopted.

On motion of Mr. Collins it was

Voted: That the Committee on the April meeting be and hereby is authorized to issue invitations to the several water companies of Connecticut requesting the attendance of their representatives at that meeting.

Voted, on motion of Mr. Hazen:

That five hundred additional copies of the JOURNAL containing

Report of Committee on the Collection of Data Relating to Awards that have been Made for Damages Resulting from the Diversion of Water be printed and that they be furnished to members at the regular rate, and to parties not members of the Association at the rate of two (2) dollars per volume.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee, at headquarters, 715 Tremont Temple, Wednesday, February 16, 1910.

Present: President King, and members Leonard Metcalf, Richard K. Hale, Michael F. Collins, Robert J. Thomas, Ermon M. Peck, and Willard Kent.

The President stated the object of the meeting to be the consideration of the subject of increased membership.

Voted: That the President appoint a committee to consider the subject of increased membership, with power to act.

The President appointed the following as members of that committee: C. W. Sherman, F. A. Barbour, E. W. Bemis, Dexter Brackett, J. H. Cook, R. C. P. Coggeshall, F. F. Forbes, Murray Forbes, Henry Roberts, J. Waldo Smith, F. P. Stearns, and F. H. Pitcher.

The President appointed the following Committee on the Annual Convention: Edwin A. Fisher, Beekman C. Little, and Emil Kuichling.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

Earle Harley Gowing.*

Died November 24, 1909.

Earle Harley Gowing was born in Woburn, Mass., July 10, 1853. His parents were Ames Gowing, born in South Reading, Mass., and Emma Genever Reed, born in Boston, Mass. He was the seventh lineal descendant of Robert Gowing, who was born in 1618 in Edinburgh, Scotland, and came to Dedham, Mass.

On graduating from the Reading High School, Mr. Gowing entered the Massachusetts Institute of Technology in 1874 as a special student in civil engineering, remaining until 1877. After leaving the Institute he entered the George F. Blake Manufacturing Company's shop in Cambridge, remaining until 1880, when he accepted a position with the Deane Steam Pump Company, working in the shop at Holyoke and in the office in New York City, and later in St. Louis. In 1883 he became assistant to George H. Barrus, consulting steam engineer and expert. From 1885 to 1888 he was engaged with B. C. Mudge, New England agent for Henry R. Worthington, selling pumping machinery, and later he constructed water works in Bath, Skowhegan, and Eastport, Me., and in Grafton, Mass. From 1888 to 1891 he completed the unfinished water works in Skowhegan, Me., and built water works at Fort Fairfield, in addition to being engaged in general engineering work.

In 1891 he entered into partnership with John J. Moore, of Hingham, Mass., under the firm name of Moore & Co., with whom he was associated at the time of his death. The firm is engaged in engineering and the construction of public works, making a specialty of water works and general contracting work. Among the water works built by this firm may be mentioned those at White-

* Memoir prepared by Richard A. Hale and Lewis M. Bancroft.

field, Lancaster, Gorham, Colebrook, N. H.; Boothbay Harbor, Phillips, Newport, Millinocket, Van Buren, Searsport, Dixfield, Me.; and Scituate, Mass.

During this period Mr. Gowing served as engineer of the water works at Machias and Oakland, Me., and engineer of the works at St. Johnsbury, Vt. He was one of the commissioners to appraise the value of the water works at Farmington, Me., and one of the commission for valuing the works at North Conway, N. H.

In 1891 Mr. Gowing entered into partnership with Mr. Barrus, under the firm name of Gowing & Co., and published the book of "Boiler Tests," written by Mr. Barrus, followed later by the publication of "Engine Tests."

Mr. Gowing was the inventor of the Gowing jointer, a device for making joints in cast-iron water pipe, which has had a large sale.

Mr. Gowing was the founder of, and, with his partner, a large owner in, the Millinocket Trust Company, Millinocket, Me. It was in their building, where he had gone for a few days to take the cashier's place in his absence, that the gas explosion occurred which caused the terrible injuries resulting in his unfortunate death.

Mr. Gowing was president and promoter of the Whitehead Association at Nantasket, and also president of the Hull and Boston line of steamers that ply between Boston and Nantasket Point.

He was the engineer and promoter of the Hingham Street Railway Company, now owned by the Massachusetts Electric Companies, and was the president of the Colebrook Water Company, and the treasurer of the Phillips Water Company, the Millinocket Water Company, the Millinocket Light Company, and the Frontier Water Company.

He was a director of all the above companies, and also of the Searsport Water Company, the Dixfield Water Company, the Scituate Water Company, the Cohasset Water Company, and the Liberty Trust Company, Boston.

Mr. Gowing was a member of the Water Board of Reading, Mass., where he had been engaged for the past five years in investigating methods of purifying and improving the water supply.

He was also member of the following societies and clubs: Boston

Society of Civil Engineers, New England Water Works Association, Technology Club, Exchange Club, Boston City Club, Economic Club, Boston Yacht Club, Unity Yacht Club, Porter's Yacht Club, Good Samaritan Lodge, A. F. & A. M., Reading; Melrose Lodge, No. 1031, B. P. O. E.

During the three years of intimate association with him at Technology, his earnestness in his work and loyalty to all traditions of school, professors, classmates, won the respect of all.

Mr. Gowing married Isabelle P. Dinsmoor, September 16, 1883, who with an adopted daughter survive to mourn his loss.

Mr. Gowing was elected a member of the New England Water Works Association, April 21, 1885.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882

Vol. XXIV. June, 1910. No. 2.

ERRATA.

1910, March Journal, Vol. XXIV, No. 1.

Page 20, bottom line, under "Location," for "Yantic River" read "Potapsco River."

Page 114, 12th line, and

Page 115, 16th line, omit the following sentences: "Daniel S. Brinsmade valued the power alone at $18 000 to $20 000. A fair value would be, perhaps, $32 000."

or less degree, over the exercise of any function of public consequence. When the owner of a private utility devotes it to a use in which the public has an interest, he, in effect, grants that public interest and, therefore, must submit to control by the public for the common good, to the extent of the interest that he has thus created. Public use is absolutely defined by the controlling conditions of the time. That which is *juris privati* to-day may be a public utility to-morrow.

Hydro-electric power, transmitted over a great area, becomes a common source of energy just as a railroad becomes a common carrier. We admit readily that a railroad is a public utility, but will it be contended that common facilities for production are

Society of Civil Engineers, New England Water Works Association, Technology Club, Exchange Club, Boston City Club, Economic Club, Boston Yacht Club, Unity Yacht Club, Porter's Yacht Club, Good Samaritan Lodge, A. F. & A. M., Reading; Melrose Lodge, No. 1031, B. P. O. E.

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NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882

Vol. XXIV. June, 1910. No. 2.

GOVERNMENTAL REGULATION OF WATER POWERS.

BY MARSHALL O. LEIGHTON, CHIEF HYDROGRAPHER, UNITED STATES GEOLOGICAL SURVEY.

[*Read January 12, 1910.*]

Up to the time of long-distance transmission of electricity a water power was essentially a local agent of production. The energy derived was used at the site and the plant was practically a private affair. Long-distance transmission, however, made water power a public utility in every sense of the term, for it entered a public market and developed a public use. Although the term *public utility* has never been strictly defined in a way that is applicable to all times and cases, the legal principle is well established. The term implies that the public, in its sovereign capacity, retains the right of regulation and control, in a greater or less degree, over the exercise of any function of public consequence. When the owner of a private utility devotes it to a use in which the public has an interest, he, in effect, grants that public interest and, therefore, must submit to control by the public for the common good, to the extent of the interest that he has thus created. Public use is absolutely defined by the controlling conditions of the time. That which is *juris privati* to-day may be a public utility to-morrow.

Hydro-electric power, transmitted over a great area, becomes a common source of energy just as a railroad becomes a common carrier. We admit readily that a railroad is a public utility, but will it be contended that common facilities for production are

any less important to public interest than common facilities for transportation? One is merely the complement of the other. Viewed from every angle, the two are identical in economic principle.

Public utility with respect to transportation facilities has been recognized in appropriate legislative acts. Public utility with respect to water power is not generally realized in this country. It is true that for many years a water power supplying energy for mills has, under interpretation of the courts, been considered a public utility, but the principle was limited in its application, and its real significance has not been appreciated. We are now facing the mature problem, and our legislative program with reference to it is hardly begun. In the most of our states, water powers are on the same legislative basis that they were years ago. The gravity of the situation has been recognized in some European countries, and in a few of the states preliminary steps have been taken.

The consequences are not entirely internal. Water-power development has become a national policy in Europe. This cannot fail to attract great industries. The water-power sites of Europe are situated close to the great markets of the world. Is there any one in the United States so confident of this country's industrial leadership as to assert that the wholesale development of those large and cheap European powers will not seriously affect our status? Trade and production are entirely cosmopolitan. The cheapest and best source of energy is going to be used, if other local conditions are favorable, without reference to any particular flag. This country has now no policy worthy of the name, and it must either meet the situation or give way to those countries that have well-defined policies.

I am in no sense a socialist. Government ownership, and especially government operation of utilities, have not, in general, commended themselves to me. But I believe that there is a world of logic in a proposal to declare by legislative enactment that all water powers are of immediate or ultimate public utility, and to govern them accordingly for the common good.

There are two sides to all questions. It should be remembered by the many advocates of government intervention that regulation and control of water-power development must not mean

repression. Hydro-electric properties have not, as a class, returned to the investor a concourse of swollen dividends. The industry has hardly passed its experimental stages. It is profitable or unprofitable according as its expenses of development and maintenance, its market and its water supply, are favorable or otherwise. No industry will respond more readily to ill-advised and oppressive legislation. In none must the burden fall more directly on the ultimate consumer. A surprisingly large number of hydro-electric developments either fail to pay dividends or become bankrupt during the first decade of existence.

There is, however, a prospective internal menace in the present situation. Current periodicals announce the formation of a water-power monopoly that promises to impose unreasonable burdens on the consumer. These accounts, when shorn of their purely spectacular features, contain a certain element of truth. Some large consolidations of water-power interests have taken place during the last few years. This, together with the appearance of the names of a few persons among the officers or in the directorate of a large number of companies operating water-power plants, making new installations, or manufacturing or marketing water-power or electric machinery, point unmistakably, if not to a water-power trust, to a concentration of ownership and administration in several groups. These groups, in the usual course of events, may consolidate or at least effect a mutual agreement. Now, the menace in such a prospect lies not so much in the probability as in the possibility of unrighteous manipulation of the public interest. The menace is, therefore, speculative, but this fact does not relieve the necessity for legislation. The nation and the states are accustomed to legislate against speculative crimes and abuses because they know from past experience that, in the present state of society, mankind is frail.

Notwithstanding all this, we must recognize the fact that consolidation is inevitable. The natural laws governing stream flow, which man cannot change if he would, make water power a natural monopoly. This is another result of electrical transmission. When a water power is utilized at the site, there is no administrative reason for the consolidation of several widely separated privileges. Under modern development the energy is

distributed over a large area. In this large area there is a common demand for power, and the whole market constitutes an administrative unit. The demand of the region is a demand in the aggregate. At the outset that demand may be supplied by the energy developed at one site on one stream. As the demand increases with the continued development of industry, the task of supplying it from one fluctuating stream grows more difficult. The energy developed at several sites or on several streams must be transmitted to supply the market. Finally, all sources of power available for that particular field of demand must be brought under a common administration so that at any time the energy may be turned hither and yon to meet the requirements of each hour. Therefore, we cannot prevent the formation of a water-power trust, and we would not prevent it if we could. No one will deny that water-power consolidation secures distinct and unusual economies and, if the consumer receives the benefit therefrom, he is better off under consolidation. Therefore, the proper solution of the problem must lie in the legislative regulation of water-power development and maintenance, to the end that the consumer shall pay a fair and reasonable price for power, consistent with the production of fair and reasonable earnings on the capital invested.

So much by way of generality. It is easy to decide that water power, being a public utility, should be subject to public regulation. It is quite another matter to frame a law or draft a code of regulations that will accomplish only laudable purposes.

Many difficulties are occasioned by the common law of riparian rights, which provides that the usufruct of water is appurtenant to the adjoining lands. The doctrine is proving less and less satisfactory as our civilization becomes more complex. Our western states are fortunate in having adopted the law of prior appropriation, based on beneficial use. The common law is in conflict with, and must surely postpone, the complete solution of the water-power problem. It substantiates every whimsical and malicious individual claim, to the utter disregard of the common good. Our western states will find it easy to solve their future water-power problems. The eastern states will eventually abrogate the common law.

Among the provisions in recent European water-power acts and legislative proposals are the following:

1. Water-power development is subject to limited concession or franchise, and its disposal is determined according to relative beneficial use. This means that the highest bidder for franchise is not successful unless his proposed use be of the greatest public utility.

2. Charges for power are regulated directly or indirectly, so that they will be equitable and discriminate.

3. A suitable rental or fee is demanded.

4. The franchise or concession may be redeemed by the government on suitable notice and proper indemnity.

5. The conveyance insures to the consignee the usufruct of rights previously acquired by other parties, but unutilized at the time of making the new grant.

There are divers other provisions, but the foregoing are all that require mention at this time.

The questions of rates and rentals provoke the widest disagreement and seem to be the most difficult of solution, as they directly affect the earnings of any plant and are theoretically a tax upon its prosperity.

Who shall say offhand what is a reasonable rate of income on a water-power investment? There are some installations on which a net dividend of 25 per cent. per annum is not too great. Such developments are in those regions where the market is temporary, as in mining districts, where it is problematical how long the ores that sustain the industry may persist. Under such conditions, a water-power development is, in all respects, equivalent to a mining proposition and should be allowed to retain profit commensurate with the risk. On the other hand, there are developments in which the market is steady and permanent, in which the structures are simple and stable, involving little expenditure for upkeep and only a small percentage for renewals. In developments of such kind a net return of 5 or 6 per cent. may be equitable. Again, the distance intervening between the power site and the market is a most important feature. The line losses, which amount to a high percentage in a transmission of 100 to 200 miles, should be taken account of in the establishment of a

legal rate schedule. Laws regulating the selling price of power should take into account this fact, and a rebate factor should be provided. Such a factor is provided in the Italian law in the assessment of rentals. For power transmitted by means of electricity to greater distances than 10 kilometers, there is granted on the annual rental of 3 francs per horse-power year a reduction calculated by multiplying the square of the distance, expressed in kilometers, by a fixed coefficient of .001. This formula embodies a principle of reduction adopted by the Congress of Electricians at Turin. The minimum charge is .5 franc. It is attained in a transmission of about 31 miles, beyond which no reduction is made. The equivalent in English measure for the above formula is the square of the distance, in miles, multiplied by .00038.

In addition to all of this, it is necessary to establish clearly just what is meant by capital. Too many well-meaning persons believe it is represented by the cost of the plant and that alone. I do not need to remind this audience how grievously mistaken such an idea is. But it is easy for the agitator to convince the public that, because a plant cost a million dollars and its net earnings are one hundred thousand dollars, the income must, therefore, be 10 per cent.

It will be of interest to review some European legislation. The economic problems with respect to hydraulic development are more intensified in Europe than in this country. All the conditions relative to property rights and the utilization of public utilities are more acute. We, in this country, may expect to encounter the same conditions when our country becomes as thickly settled and our individual interests become common interests to the extent that they have in European countries. While we may not find it necessary to adopt European laws and regulations in detail, it will be wise in the adjustment of our own problems to ascertain what these older countries have found it necessary to do. We will consider first the condition in Switzerland, a water-power country of the first rank.

Previous to October 25, 1908, each of the twenty-five cantons of Switzerland had jurisdiction over the waters within its boundaries, and the cantonal authorities regulated their water powers in accordance with diverse principles. It will not be possible here

to examine them all, and we will, therefore, consider a typical case, namely, the Canton of Berne.

Public ownership is common. Berne has made the practice of granting concessions for water-power development to groups of communities. The public policy there is well interpreted in a statement of the director of public works made in October, 1891, and ratified by the Grand Council of the canton, as follows:

"We consider that it is the communities on whom the law imposes the obligation of establishing and maintaining dikes and dams and who, for years and for centuries, have had to bear the expense of maintaining the banks and protection works, without taking into consideration the great damage to which they are often subject on account of inundations, that should profit by the wealth that lies in the utilization of water powers. They have the first right to obtain concessions, and the undersigned [M. Dinkelmann, Director of Public Works, October, 1891] misses no opportunity to call the attention of the representatives of the commune authorities to this fact. All demands for concessions must be published and the specifications filed in the proper communes. The authorities of the commune can oppose them and can intervene as applicant and thus secure by cheap water power the means of sustaining and improving their industries. It is thus our purpose to have the country itself profit by the water powers located within it."

The advisability of placing control of waters and water powers under federal government was investigated under the direction of the Swiss Federal Council from 1892 to 1894. It was found, at the time, inadvisable to make such a change, but the Federal Council did, nevertheless, recommend to the cantons the incorporation of uniform laws based on the following principles:

1. All water powers shall be considered as of public utility.

2. Compulsory mutualization of all water-power interests along a water course with respect to the utilization of hydraulic energy.

3. The right of the cantonal authorities to investigate the industrial value of proposed enterprises and to base their decisions relative to applications for power sites on the results thereof; also, their right to reserve to their own use or that of an interested commune any power site.

4. In case of damages sustained by the owners of water-power

plants by reason of changes made in the regimen of water courses in the public interest, said owners shall not be entitled to indemnity.

5. The limitation of the term of the concession to a fixed number of years, with clauses of forfeiture in case of non-utilization or of redemption by the canton.

The above procedure of the Federal Council shows clearly that the need was felt at the time for uniformity in administration of water powers within the republic, but that public opinion had not yet united in favor of centralization to a degree sufficient to give the members of the council confidence in supporting so radical a measure. A little more time and a little more difficulty with the prevailing conditions was apparently necessary. It required fourteen years more of thought and experience to convince the people of the Swiss republic that necessity and not legal precedent governs the proper course of procedure with reference to water power. On October 25, 1908, by a popular vote of 292 997 against 52 180 in opposition, an amendment to the Constitution was adopted which provides for the centralization of authority over water powers. The amendment reads approximately as follows:

"The Federal Congress shall have supervision over the development of water powers, shall make provision for the disposition of water-rights concessions, and shall regulate the transmission and distribution of electrical energy, so far as may be necessary to protect the public interest and to provide for the proper development of such resources; all water rights to which the terms of the Federal law do not extend shall be under the jurisdiction of the cantons, which shall dispose of the concessions, regulate the same, and impose taxes and fees for their use, but such regulation, taxes, and fees shall not be so severe as to prevent or inhibit the development of water powers. The national government shall regulate and dispose of concessions for powers located on intercantonal and international boundary streams and shall determine the taxes and fees to be imposed thereon, after hearing has been granted to the cantons interested, but such taxes and fees shall be collected by the cantons. No power located on a stream within the republic shall be transmitted to a foreign country without the consent of the Federal Council. The provisions of Federal law shall apply to water-rights concessions already existing, except in cases specifically exempted therefrom by law."

This step taken by the Swiss people is interesting especially because the public policy had already become fixed with reference to the governmental regulation of water powers. The new legislation merely goes an important step further. Many of the cantonal laws were already excellent in their operation. We would have to take a long step forward to reach the advanced stage of the old Swiss cantonal legislation. Yet, it proved not good enough for the Swiss people.

Let us now consider Italian legislation.

In Italy, bodies of water that are susceptible of serving public purposes are designated as *public waters* and are subject to the control of the sovereign. The organic law of August 10, 1884, regulating the diversion of public waters, provides for their use by concession, which is granted by virtue of the payment of rent. The concession fixes the quantity of water allowed to be diverted, the conditions of the diversion, the rental, and the requisite guarantees in favor of agriculture, industry, and the public health. The concession is granted for thirty years or less, but is renewable in favor of the first concessionaire for new periods of thirty years, unless he, in the opinion of the administration, has attained the purpose for which the concession was granted to him. This is a remarkable provision from all points of view, as it gives to the government authority to refuse, in the interest of the public, a renewal of concession, even though the concessionaire may offer to the government greater inducements than can be secured from any other applicant.

If, during the period of any concession, the regimen of the water course is changed by the government for any public interest, the concessionaire is not entitled to any indemnity for damages occasioned thereby, although he may secure a proportionate reduction in rent or a cancellation of the concession.

The rental is 3 francs, or about 55 cents per horse-power year.

It appears that this organic law was, in the opinion of the people of Italy, not sufficient to properly conserve water powers, and after the publication of several administrative decrees, in each of which the law was more and more liberally construed in favor of the state, a commission was appointed, under a decree of August 16, 1898, for the purpose of reforming the law. There are re-

viewed below some of the important recommendations of this commission.

No application is considered unless preceded by examination by a permanent special commission, which determines whether, irrespective of the application in hand, there is legitimate public interest or any present or future need of the state that interferes with the granting of any concession. If, in the interest of the public service, the state finds it desirable to utilize or reserve any water power in any manner, public utility is declared by decree, and all individual applications that cannot technically coexist with the government project are denied.

Another provision intended to reduce the chances for speculation provides that the concessionaire of a public water diversion must remain in connection with it up to the time of the organization of the company, and forbids, under penalty of forfeiture, the transfer to a third party of a concession for the diversion of public waters in any manner before such concession shall have been entirely utilized.

Still another provision gives the state the right to intervene in the case of all concessions in which the maximum use of the power is not made. If the concessionaire neglects or refuses to develop his power to the maximum usefulness, the concession may be turned over to a third party who agrees to make the necessary improvements and the first concessionaire is protected merely by compensation in kind. It is obvious that this provision prevents any concessionaire from manipulating the market by depressing the productivity of any property.

Rebate on rental according to the distance of transmission is provided in this law, as has already been explained.

The law provides that the concession when granted shall be free from all claims in contest. All needful public hearings are provided before granting the concession and it is assumed that any party having a claim that contests an application for concession will present the same at the designated time. If, notwithstanding such presentation, the concession is granted, the concessionaire is secure against all future interference suits. Such a provision is of inestimable value to the promoters of any power scheme. It provides a sovereign guarantee. Many power com-

panies in this country, which have defended costly and malicious suits, some of which may with propriety be termed blackmail, would be glad to avail themselves of such a provision.

We will now consider legislation in France.

The water-power problems in this country have developed an illuminating discussion, and the literature on the subject is copious. The problem in France is somewhat similar, though in no wise as serious as in this country. The French people are fully awake to the situation and have accomplished much, while we are in the initial stages of being aroused.

The laws distinguish between navigable and non-navigable water courses. The former are a part of the public domain and the owners of adjoining property have no rights in the water. The federal government grants concessions for water-power development where and when it believes wise, but such concessions, like all others granted over the public domaln, are precarious and can be revoked without indemnity. The water in non-navigable courses is not domain, and, while the ownership of adjoining lands extends to midstream, the bank owners have merely the usufruct of the water, subject to the rights of other riparian owners, under a government permit.

The measure designed to regulate water powers on the public domain which seems to have the most general support is one reported on to the Chamber of Deputies by a special commission in the session of 1908. It provides that power plants shall be classified as "authorized plants" and "plants under concession." Authorized plants are defined as those which develop a gross energy at low water of not more than 200 *poncelets*,* while power plants under concession include all which have a greater capacity. The authorized power plants are governed by laws and regulations now in force, but they are subject to cancellation and are not granted for a period greater than fifty years. The surplus power of any authorized plant may, under exceptional conditions, be sold to the public under regulations promulgated by the commissioner of public works.

Power plants under concession are limited to a specified term, while those developing a horse power greater than the equivalent

* A *poncelet* equals 1.33 horse power.

of 15 000 *poncelets* cannot be concessioned except by special enactment in Parliament. The Articles of Concession specify: *first,* the location of the plant; *second,* the duration of concession; *third,* the character of the appurtenant works; *fourth,* the amount of water to be used, together with provisions that safeguard navigation and public health, domestic water supply and irrigation, provide protection against floods, and preserve the beauty of the landscape; *fifth,* the amount of rental to be paid; *sixth,* the sureties; *seventh,* the maximum charges for sale of power to the public; *eighth,* the amount of power to be reserved for the benefit of the public services, and the conditions under which the same shall be placed at public disposal; *ninth,* the purpose of state control; *tenth,* the conditions under which the right of redemption shall be exercised by the government; and, *eleventh,* the rights and duties of the concessionaire in general, both during the concession period and at its expiration.

The law further provides that all the power-plant appurtenances, including real property and rights of way, shall become a part of the public domain. At the expiration of any concession the state shall immediately take possession of the power plant without liability for indemnity. It is further provided that all power plants which have, in whole or in part, been declared of public utility, and those under concession which do not have for their principal purpose the sale of power, may at all times dispose of excess power not utilized in the regular operation of the plant under conditions fixed by the state council.

Another law governing the development of powers on non-navigable streams was favorably reported on to the Chamber of Deputies in the session of 1908 by a special commission appointed to consider the whole matter. It has already been cited that, although the owners of banks along any non-navigable stream are entitled, under the organic law, to the usufruct of water therein, no power can be developed without a permit from the government. This, of course, is an apparent contradiction in the system of jurisprudence, but it may be explained by the significance of the term "permit" as opposed to that of the concession. The water-power promoter who receives a concession from the French government is vested with rights and privileges that he has not

hitherto possessed. The permit, on the other hand, is merely an authorization. It recognizes the state as the guardian of all public and private interests, and the act of authorization consists in the removal of certain obstacles in the way of private activity. This permits the exercise of a right that existed in substance previous to the application for the permit. Under the system of authorization the proprietor of both banks of a stream is never refused the right to develop the water power. The practical effect of the authorization system is that he is denied the right of not using it. The facts are that water powers on non-navigable streams may be found to be of public utility and, while the private citizen is freely allowed to realize a profit from his possessions, it is conceded that, from the standpoint of the common good, he ought to prove the general utility of his enterprise and satisfy the government that its development along the lines laid down by him will not interfere with larger developments for public utility. In other words, the provision has the purpose of conserving the water power, which is merely another way of insuring that it shall be used to the maximum public benefit.

Now, the law above cited does not propose a change in the obligation to secure an administrative permit, but it defines the power of the government with reference thereto more specifically. It provides that the petitioner must indicate the location of the works and the use to be made thereof, must prove that he possesses the lands necessary, which must be at least one third of the total length of the banks in the section under consideration. The application is subject to examination, and it is decreed by the Council of State whether the request shall be granted or denied. The permit is barred by limitation if the work is not executed within three years after the permit is issued, and the permit may always be withdrawn by decree of the Council of State if the conditions prescribed in the issuance thereof for the protection of public interest have not been complied with. The permit specifies the precautions that must be taken for the protection of the general public, especially concerning public health, floods, domestic water supplies, irrigation, and fisheries. During the first ten years immediately succeeding the beginning of operation of the plant, any public authority may requisition the site for the public

service, with suitable indemnity, or any public authority may requisition a part of the product of the plant. Hydraulic plants may be established by third parties on private property by virtue of a declaration of public utility, upon payment of a proper indemnity to the owner of the rights, whether or not said owner agrees. The only condition is that of public utility and, when such utility is declared, the power plant, together with appurtenant realty and equipment, becomes a part of the public domain. All of this legislation insures the development and utilization of water powers in accordance with their maximum public usefulness and prevents the holder of the property from exercising his rights to the detriment of public interest.

Opportunity is not here afforded to review the measures adopted by other countries, and it will be appreciated that the writer has not had an opportunity to discuss or analyze in any worthy way the principles upon which power legislation is justified. It is believed that enough has been said to indicate what is the attitude of at least three European countries. It would be interesting to review such legislation in the United States, but that is already more or less familiar to many of the members of this association. In only one case, namely, that of the forest service in the administration of water powers on national forests, is there any approach to the regulative authority that has been found to be necessary in the case of European powers.

The water powers of this country have a higher ultimate significance than is generally conceded to them. They are certain to have a dominating effect on the material progress of this republic. In the old world it has been decided that a proper function of government is to declare water powers of public utility and to place them under appropriate laws, the assumption being that the public has a dominant interest in the development of this great natural resource.

No one can safely predict the final form of laws to be enacted to this end. Whether they will lead to government ownership and control, whether in this country the state or national government shall control, are matters for the future to determine. If our present form of government proves to be all-sufficient in this respect, then it will prevail. At least three European countries

have found it necessary to make water power a national matter. This paper is not to be considered as a plea for nationalization. The author does not at present support that view, but he is impressed with the fact that necessity and not legal precedent must eventually direct the course of procedure. It can hardly be expected that when the necessity arrives it will readily be recognized and accepted. Acceptance will be postponed, at enormous cost, until the people can secure a clear vision above the mist of legal precedents. The great difficulty will not be to regulate water-power development and operation, but to convince many persons that a thing may be necessary, even though it involve a change in our habits of thought.

DISCUSSION.

Prof. Dugald C. Jackson.* I think that probably all of us may be ranked as conservationists, and consequently we all believe that the water powers should have something done for them. As a matter of fact, this country needs encouragement in the development of water powers rather than discouragement. Many things have been said by talking conservationists which seem to indicate a desire to control water powers in various ways that are not wisely considered and would tend to discourage development; but we need encouragement for the development of water powers, wherever such development is economical and sound, instead of discouragement. It seems to me that properly safeguarded encouragement might be worked out by constructive statesmanship in ways resembling those worked out through the Carey Act and its related enactments for the development of the use of water for irrigation purposes.

There are three sound grounds upon which we need development of water powers. One is to conserve comfort and convenience, another is to conserve other natural resources, and the third is to maintain an industrial eminence. In respect to the former, this country needs a network of power lines throughout its entire area where it is densely populated, whereby any person may be able to get power as we get gas, water, and electric power in the cities. That is coming to pass in a few portions of the

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country. It is coming to pass in the Carolinas, and in certain portions of New York State, for instance; it has come to pass in portions of the European countries, especially the northern part of Italy. The effect upon the development of the country and the ease of life which would arise from this farm-to-farm distribution of power is really inconceivable to those of us who have not experienced its benefits. This extension of power lines will increase the comfort and profit of country life and do much to regenerate interest in farm life as contrasted with city life. If we are to enjoy such advantages, we must encourage the fullest development of our sources of water power in all the well-populated portions of the country.

Now, let us look at the matter for a moment from the standpoint of the conservation of our other natural resources. Our methods of using steam-generated power for industrial purposes are quite uneconomical. I presume that on the average we use in our industrial plants six or seven pounds of coal per horse power developed, and on that basis a horse power developed from an hydraulic plant for ten hours a day, operating for the working days of the year, means a saving of about ten tons of coal in a year; and a million horse power (a figure mentioned by Mr. Leighton) means a tremendous saving from that point of view. I do not mean that the water power will necessarily in every instance supplant fuel-using power where steam plants are now installed, but I mean that it will either supplant fuel-using power now installed, or else it becomes a substitute for fuel-using power which might be installed were the water power not available; each horse power developed from water means an important conserving of fuel, and, consequently, we need all the development of water power which can be made succesfully from an economic standpoint. Encouragement of such development is of the utmost importance.

On the other hand, we do need such control of water-power sites as will keep speculators, who do not themselves intend to develop the powers, from getting control and preventing development by holding the properties at a speculative price. There are, therefore, two things to be avoided: One is government control of a kind which tends to prevent rapid development, —

substituted for that we should have encouragement of development wherever such development is economically sound,—and the other is failure to control the power sites in a way that will prevent speculators from securing water powers and holding them for a future rise in price. There are things to be avoided and, on the other hand, there are things we need; and I believe that only after some more years of threshing out these questions we will come, in this country, to a reasonable and just view of what is right. I think that water power is a public utility, but I do not believe that a man who has an ownership in a waterfall and the land on either side should have his property seized by the government or absolutely controlled by the government. I do believe that wherever practicable he should be encouraged to put that waterfall into use for economic service.

Prof. George F. Swain.* I fully believe that the time has come for this question of the regulation of water powers in this country to be taken up and acted upon by the American people. I believe that legislation is coming. Of course, that legislation should have, as Professor Jackson has said, these two objects in view: To regulate and to protect the rights of the public on the one hand, without repressing development on the other. In our western country development is the thing that is needed, but in the present state of the public mind in this country I think that, perhaps, too much attention is paid to protecting the rights of the public at the expense of those who would like to develop our resources.

I have been especially interested in Mr. Leighton's remarks with reference to a 25 per cent. dividend in some cases not being too great. That leads me to suggest that any legislation on this subject will involve a good many points which will have to be covered in a broad way only, and not specifically. A great deal of discretion will have to be left, in any case, to those who administer the law, and it will, therefore, be of great importance that such law should be administered by persons who hold their positions not temporarily, but for considerable periods of time, — persons who are familiar with the subject and who are determined to administer the law in a liberal and broad-minded spirit.

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In regard to practice in foreign countries, I think such practice should be considered more with reference to its general aspects than its specific provisions. The latter are no safe guide to us, because the local conditions are very different, but the general tendencies may be worthy of imitation.

PROF. DWIGHT PORTER.* I have been a little curious, in hearing of these apparently wise provisions which have been adopted in foreign countries, as to how they have actually worked out in practice. They are in part designed to protect the public, and I wonder whether Mr. Leighton is informed as to what the experience has been with them. Have they really given this protection, and have they been carried out with freedom from friction and to the general satisfaction of the people?

MR. LEIGHTON. Of course, Mr. President, all these laws have been discussed, antagonized, and supported abroad, just as they are in every live country. In some cases they have not been laws for a sufficient length of time to test them practically, but in the case of Switzerland and in the case of Italy they certainly have been a great success. The laws have been wisely administered, and they have actually encouraged the development of water power.

All the laws of those countries are not acting against the water-power people. Some of them are in actual encouragement of the water-power people as against the public as a whole, you might say. For example, under a concession in Italy a man who gets a water-power concession is absolutely protected by government title. He does not have to submit to the malicious suits such as are common in this country. I know of a great many water-power companies that would be glad to incorporate under the laws of Italy, simply for the protection that they would get.

On the whole, I am quite ready to state that these laws have done all that they were expected to do, and more. Indeed, the very fact that more stringent laws which increase the scope of government control are continually being agitated and frequently enacted is an index of the practical effect of the restrictions and the methods of the use of water power as regulated and developed.

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THE PURCHASE OF COAL ON AN EFFICIENCY BASIS.

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Conservation of the national resources is a subject which is attracting much attention at the present time, and as coal is one of the most important of these resources, and one which cannot be replaced when the supply is exhausted, it is very desirable that efforts to prevent waste both in mining and using coal should be encouraged. Any improvement in methods or apparatus tending to increased efficiency in the use of fuel not only benefits the individual consumer who adopts these improvements, but also assists in the conservation of this most important resource.

The development of the modern high-duty steam engine, in the larger units, has now reached a point where but little increase in economy can be expected from further improvements. Attention, therefore, has been transferred to the steam generator, the boiler and furnace, and it is through improvement in design and operation of the boiler-room equipment, and in the purchase and burning of coal, that the greatest increase in efficiency may be expected.

Until quite recently coal was purchased with but little regard to its heating value, the common practice being to use the trade name when ordering, as Georges Creek, Pocahontas, New River, etc.

The difficulty with this method was that even if the dealer furnished the kind of coal called for, there was no guarantee that the coal would be of uniform quality. Such names refer to mining districts, which contain many mines, the output from which shows great variation, due both to the different quality of coal in the various mines and to the degree of care used in preparing the product for market.

Even if the coal is specified to come from a particular mine, there will still be some variation in quality, and there will be the additional disadvantage that through strikes or accidents the supply from this mine may suddenly be cut off.

The greatest disadvantage, however, of the old method of purchasing coal is that in case of variation in the quality supplied there is no definite basis of settlement between the dealer and consumer. This works to the disadvantage of both parties, as sometimes, when the dealer supplies a good coal, trouble is caused by the firemen being unaccustomed to firing this particular kind, or by the boiler plant being unfitted to burn the coal efficiently, or by the general tendency to blame the coal for any falling off in economy which is observed in the operation of the plant. On the other hand, the dealer may deliver coal far below the standard and claim that it must be good because the same kind of coal is giving other customers good satisfaction, and that the trouble must be in the customer's fire-room.

Without chemical analysis or calorimeter tests, it is very difficult to prove that the coal is bad, or at least to convince the dealer of the fact. And, moreover, even if the case is proved, there is no basis of adjustment. The result is, in most cases, that the coal must be used and paid for at the full contract price, often to the serious financial loss of the consumer if the amount of poor coal is large.

The dealers were at first much opposed to specifications based on heating value. This opposition was due in part to conservatism, as it is exceedingly hard to change trade customs and methods, and in part to unwise and unduly severe requirements in some of the earlier specifications. Now, however, the more progressive coal operators and dealers favor such a method, as it furnishes a definite basis of agreement covering variation in quality, terms of settlement, etc., and provides, by means of premium and penalty clauses, an incentive to furnish a superior quality of coal. The honest dealer is also protected from unfair competition, as it was a common occurrence, when proposals were requested for furnishing a particular kind of coal specified by name, for unscrupulous concerns to bid a low price with the intention of furnishing a cheaper grade of coal if they secured the contract. This course would not be profitable in case of a contract made on a heat unit basis, as the inferior coal would either be paid for at a low price or rejected.

In drawing up specifications it is of the utmost importance that

the interests of both the dealer and consumer shall be thoroughly protected and that the requirements shall be made as simple and plain as is consistent with securing the desired result.

The most economical coal to buy is the one that will make steam for the least cost, all things considered. This does not mean necessarily the cheapest coal, or even the coal which will evaporate water at the least cost considering the price of coal alone.

The first step, therefore, in formulating specifications is to find out what kind of coal will give the best results in the particular plant where it is to be used, and to make such requirements as will insure the delivery of the desired quality.

The principal points which should be covered by the specifications are as follows: The total amount of coal desired; the rate of delivery; the approximate proportions of lump and fine coal; a statement of the approximate composition of the coal desired, including the percentages of ash, sulphur, and volatile matter; the heat units per pound desired, and the maximum limits of ash, moisture, sulphur, and volatile matter which will be accepted. The method of determining the amount to be paid for, whether by bill of lading or by delivery weights, the method of taking samples, for conducting tests, for making corrections in contract price for quality, should be stated and there should be a clearly defined provision for settlement of differences which may arise between dealer and consumer.

Provision should also be made for purchasing a limited amount of coal from other dealers for test purposes if so desired, for procedure in case the contractor fails to deliver coal when requested, and for increasing or diminishing the contract amount by a certain percentage if conditions of operation make such a course advisable.

It may be of interest to point out some of the considerations which ordinarily govern a purchaser in selecting the proper kind of fuel, and to show the effect of the impurities and other constituents of the coal.

The location of the plant is an important matter, for it determines the freight rate and cost of whatever teaming may be necessary. As the transportation charges are generally the same per ton for all grades of coal, it follows that the larger the proportion

this expense is of the total cost of the coal, the more advantageous it is to use the higher grades of fuel. It is important to select a kind of coal which will not be subject to annoying and expensive interruptions in delivery.

If transportation rates are such that the purchase of lower grade coal would apparently be profitable, the plant equipment and conditions of operation should be carefully considered to see if there is sufficient boiler capacity when burning fuel of low heating value, and if the grate and draft conditions are suitable. If the plant is not suitably arranged, a study should be made to determine if the probable saving resulting from using the low grade coal will warrant the expense of any changes in equipment which may be necessary. A study of the labor conditions is also important, as the poorer the quality of the coal, the greater the amount that has to be handled, resulting in an increase in the work of keeping the fires in order and of removing the ashes.

The size of coal is also of considerable importance, uniformity of size as a rule giving the best results. Some of the best steam coal is of a very friable nature and, if subjected to several handlings before reaching the consumers' bins, it may be delivered in a powdered condition. Coal in this form has a tendency to clog the air passages in the fuel bed, causing imperfect combustion, and to fall through the grate into the ash pit, thereby increasing the waste. The effect of fine coal is particularly bad when the smaller sizes of anthracite are used with it. On the other hand, some semi-anthracite coal is exceeding hard and is delivered in large lumps, which break the coal-handling equipment and cause extra labor in the fire-room, as the lumps have to be broken up with a heavy hammer before they can be burned.

The amount and composition of the ash has much to do with the value of a coal, for freight and handling charges must be paid on the incombustible material and, in many cases, the ashes have to be carted away at considerable expense.

A coal with a large percentage of ash clogs the fire, thus checking the draft and causing incomplete combustion and requiring more frequent cleaning of the fires, which causes a waste of coal, as a considerable amount of combustible material is carried into the ashpit with the clinkers. In such a case, moreover, the fire doors

have to be opened more frequently, thus cooling off the gases and causing unequal expansion in the boiler plates, and the ash is heated to the furnace temperature and much of this heat is wasted. The fusible constituents of such a coal form clinkers, which increase the labor of firing and interfere with proper combustion. The percentage of ash may be considerably reduced by careful preparation at the mine.

There is some moisture, generally about one per cent., in the coal when mined, and as coal is transported in open cars, the amount of moisture may be either diminished or increased according to weather conditions prevailing during the time the coal is exposed in the cars. Ordinary bituminous coal will hold about five per cent. of moisture without dripping. This water is, of course, worse than useless to the consumer, as he has to pay all charges on it, and in addition loses the heat required to evaporate it and superheat the steam in the furnace. Coal containing a large amount of moisture, if delivered in cold weather, is exceedingly hard to unload, as the contents of the cars are frozen into a solid mass requiring hard labor with the pick to break.

Sulphur generally occurs in coal as iron pyrites or sulphide of iron, and sometimes in cubical crystals resembling brass, or in combination with lime as sulphate of calcium or gypsum. It also sometimes occurs in a free state.

While sulphur is combustible, its heating value is less than one third that of carbon. A considerable amount of the sulphur in coal does not burn, but remains in combination with the other constituents of the ash, causing the worst kind of clinkers, particularly if the coal is high in sulphur and iron with a small percentage of ash, when it forms a tough slag, which is almost impossible to break up, and which in some cases unites with the cast-iron grate bars and quickly ruins them. The sulphur which is burned forms a gas which in the presence of moisture generates an acid, which quickly corrodes the iron work of flues and stacks, while the ashes and clinkers which gather on metal surfaces also have a powerful corrosive action if they become moist.

It was formerly thought that sulphur was the cause of the so-called spontaneous combustion of coal, but, although it is a fact that coals containing a high percentage of sulphur often give

trouble from heating, there are coals which contain but a small amount of sulphur which heat badly; and the amount of sulphur in coal is far too small to account for the rise in temperature of the pile, even if it were all oxidized, which is never the case. While the cause of heating is not fully understood, it appears to be due to the structure and mechanical condition of the coal rather than to its chemical composition. Some coals seem to have the property of absorbing oxygen, with consequent rise in temperature, and as the heat increases, the affinity for oxygen seems to increase until, under favorable circumstances, the coal becomes ignited.

Finely divided, freshly mined coal having a considerable amount of volatile material and moisture and stored in large masses is apt to heat. As a rule, the heating is not uniform throughout the mass, but starts at certain points in the pile where favorable conditions exist, such as near partitions or around pillars, where a supply of oxygen may be had without sufficient radiation to remove the heat as fast as formed. The small ventilating pipes which are sometimes installed with a view to preventing heating furnish ideal spots for starting fires.

The effect of volatile matter in coal depends largely on the type of furnace and boiler in which it is to be used, as with proper equipment coal containing very large percentages of volatile matter may be burned with economy and practically without smoke. With the ordinary steam plant, however, coal having a volatile content below 22 per cent. will prove more efficient and give less trouble on account of smoke.

The combustible volatile matter consists principally of hydrocarbons, methane or marsh gas (CH_4) being the most important. Ethylene (olefiant gas) (C_2H_4) is also a constituent. A considerable proportion of the volatile matter is non-combustible, consisting of water of composition which is not driven off at the temperature of the drying oven. The inert matter varies from about 4 per cent. of the total weight in eastern coals to 14 per cent. in western coals. There is also from 1 per cent. to $1\frac{1}{2}$ per cent. of nitrogen and small quantities of carbonic acid (CO_2). The combustible portion of the volatile matter has a high heating value, owing to the hydrocarbons. Methane has a calorific capacity of 23 600, while carbon has 14 544 and sulphur 4 050

B.t.u.* per pound. Consequently, a high volatile coal will often give a high result when tested in the calorimeter, but when burned in the furnace the evaporation results may be disappointing unless the equipment is suitable. The volatile matter distills off rapidly from the green coal, tending to lower the furnace temperature below the ignition point; it is also difficult to get the gases mixed with the proper proportion of highly heated air and provide space enough for them to be completely burned before coming into contact with the water-heating surfaces of the boiler. For this reason it is important to limit the percentage of volatile matter to an amount which will give satisfaction in the particular plant where the coal is to be used.

TESTS.

The most important part of the testing operation is obtaining a sample which shall represent as nearly as possible the true average quality of the lot of coal to be tested. This is best accomplished by taking small portions from all parts of the shipment to be sampled, being careful to preserve the same proportions of lumps and fine in the sample as in the lot from which it is taken. The amount of the sample thus taken should be governed somewhat by the size of the shipment to be tested, but it should not be less than a bushel in any case.

The sample should be spread out on a clean, hard surface — an iron plate is best, but a clean floor will do — and the large lumps broken with a hammer. After the coal is thoroughly mixed, the pile should be flattened out in circular form and divided into quarters by drawing diameters at right angles. The opposite quarters should be rejected, and the operation repeated, breaking the lumps finer each time, until about a quart remains. This is the sample to be tested, and it should be sent to the testing laboratory in an air-tight metal or glass receptacle. All the operations described should be carried out as rapidly as possible to avoid loss of moisture.

It was formerly the custom to make a complete analysis of the coal, including moisture, ash, total carbon, hydrogen, oxygen,

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* British thermal unit, the amount of heat required to raise the temperature of one pound of water 1° F.

nitrogen, and sulphur. This is often called ultimate analysis. The heating effect may be calculated by the Dulong formula,

$$\text{B.t.u.} = 14\,600\,C + 62\,000\,(H - \tfrac{1}{8}O) + 4\,050\,S,$$

in which B.t.u. represents the heat derived from the combustion of one pound of the coal, C, H, O, and S being the percentages, expressed as decimals, of carbon, hydrogen, oxygen, and sulphur found by analysis. The term $H - \frac{1}{8}O$ is used in accordance with Dulong's theory that the oxygen present in the coal with sufficient hydrogen to combine with it and form water should be considered inert. One pound of oxygen requires one eighth of a pound of hydrogen to form the combination.

At the present time the practice is to make an approximate analysis, which includes the determination of moisture, ash, volatile matter, and sometimes sulphur. The calorific value is obtained by burning a small portion of the powdered sample in a calorimeter.

There are several types of this apparatus in use, but the bomb calorimeter gives the most accurate results and is now used in the best laboratories. This instrument consists of a very strongly constructed steel or bronze shell, fitted with a screw cap, or, if in a spherical form, with a screw joint in the middle. The interior surface is lined with porcelain, nickel, or platinum, or sometimes with a heavy gold plate, the object being to produce a surface that will resist the corrosive action of the acids generated by the combustion.

A carefully weighed amount of finely powdered coal is placed in a small platinum pan suspended in the interior of the bomb, a platinum fuse wire is arranged to ignite the charge, and the bomb is then filled with oxygen gas under a pressure of three hundred pounds per square inch and placed in a vessel containing a weighed amount of water, the bomb being completely submerged. After the temperature of the water has been equalized by means of a stirring device, the coal is ignited by sending an electric current through the fuse wire. The heat derived from the combustion is absorbed by the water, the metallic parts of the bomb, the stirrer, and the jacket. The rise of temperature of the water is observed by means of a carefully calibrated thermometer, and from this

reading, corrected for the heat absorbed by the metal parts of the bomb, and for radiation, the heating effect of the coal is calculated. In order to obtain accurate results the greatest care must be used in every part of the operation, and the thermometer must be extremely accurate and should be read to thousandths of a degree; it is best to use a thermometer which has been tested at the United States Bureau of Standards in Washington.

The amount of ash is determined by burning an accurately weighed portion of the coal in a platinum crucible over a Bunsen burner until all trace of carbon has disappeared; the ash is then cooled, weighed, and the percentage calculated.

The volatile matter is determined by heating a weighed amount of the dry, powdered coal over a Bunsen burner flame of standard height for a fixed time, usually seven minutes; the loss of weight is considered to be the amount of volatile matter.

Moisture is estimated by drying the sample at a temperature of 105° C., equivalent to 221° F., for one hour in an oven fitted with a heat regulator. Sometimes a large sample of the coal is spread out in a shallow pan and allowed to dry for twenty-four hours at the ordinary temperature; the coal is then said to be air dried. The remainder of the moisture is then determined on a small sample by drying in an oven as previously described.

Sulphur is determined by Eschka's method, which consists in heating the coal with magnesium oxide, sodium carbonate, and ammonium nitrate in a platinum dish, using an alcohol flame to avoid the sulphur in ordinary illuminating gas, dissolving the resulting mass in dilute hydrochloric acid, filtering and determining the sulphuric acid in the filtrate with barium chloride.

Fixed carbon is calculated by subtracting the percentages of ash, moisture, volatile matter, and sulphur from 100.

The practical test made by burning the coal in the boiler furnace is advocated by many engineers as the only satisfactory way to test coal, and it has some advantages if enough coal is available to make a test of sufficient duration.

The actual evaporation under working conditions, the character and amount of ash and clinkers, the tendency to smoke, and other valuable information may be obtained from this test. Comparatively few plants, however, are equipped with the facilities to make

satisfactory boiler tests, and it is very difficult in any case to make these tests, using different kinds of coal, under conditions which are strictly comparable. It often takes some time for the fireman to learn how to burn a coal with which he is not familiar in a way to get the best results, and sometimes he is prejudiced and does not give the coal a fair test.

The best practice is to make an approximate analysis and a calorimeter test of the coal, supplemented by a practical test under the boiler, using a sufficiently large amount of coal for a run of at least forty-eight hours' duration, noting carefully the amount of water evaporated per pound of coal, the character and amount of ash, and quantity and color of the smoke.

Where a considerable number of coals are offered in competition, it is generally possible to eliminate all but two or three from consideration by means of the approximate analysis, calorimeter test, and price. By making a practical test of the remaining coals under working conditions one should be able to choose the coal which will be the most satisfactory, all things considered.

But little consideration should be paid to small samples furnished by dealers, or to reports of analysis published by them, as it is quite easy to sélect a small sample of good coal from a pretty poor lot and to get a chemist's report on it which will be very misleading in regard to the average quality of the coal in question.

The better way is to take a sample either personally or by an experienced representative from some lot or cargo of the coal under investigation and use this in making the tests.

SPECIFICATIONS.

The United States government in buying coal for the federal buildings uses a specification based on the heating value of the coal as delivered at the place where it is to be used. In order to establish a standard for comparison of bids and for payment if the proposal is accepted, the bidder is required to state the price per ton, the B.t.u., and the amount of ash in the dry coal which he proposes to furnish.

The price named in the proposal is increased or decreased on a percentage basis for variation in quality above and below the standard set by the dealer. For example, if the calorimeter tests

show that the heating capacity in B.t.u. of the coal is 2 per cent. more or less than the established standard, the price will be increased or decreased 2 per cent. The price is further corrected for ash by payment of a premium of one cent per ton for each whole per cent. of ash less than the standard established by the dealer, and if the ash is 2 per cent. more than the standard a deduction is made, varying from 2 cents to 18 cents per ton, according to a schedule, with an increasing penalty rate as the percentage of ash increases. There is a fixed maximum of ash, volatile matter, sulphur, and proportion of fine dust. If these limits are exceeded, the coal is subject to rejection. These maximum percentages vary in different sections of the country in order to conform to the composition of the coal which may be obtained in the local market.

The Commercial Testing and Engineering Company of Chicago have a standard form of specification which is used by their clients.

A contract grade is established by the dealer, who states the percentage of moisture in the coal as delivered, the percentage of ash in the dry coal, and the B.t.u. per pound of dry coal. From these data a *contract guarantee* called the *net B.t.u. for one cent* is computed by multiplying the number of B.t.u. per pound of dry coal by the percentage of moisture expressed in decimals, subtracting the product so found from the number of B.t.u. per pound of dry coal, multiplying the remainder by 2 000, and dividing the product by the rate per ton, expressed as cents, plus one half of the ash percentage expressed as cents.

Samples of the coal as delivered are taken by the consumer and are forwarded to the engineering company for analysis. The payments are made on a basis of delivered values, obtained by dividing the number of B.t.u. in a ton of 2 000 pounds of moist coal by the *contract guarantee* and subtracting from the quotient expressed as dollars and cents one half of the dry ash percentage delivered, also expressed as cents.

Coal containing 3 per cent. more ash, 5 per cent. more moisture, and 500 fewer B.t.u. per pound of dry coal than specified in the contract grade may be accepted; beyond these limits the coal is subject to rejection. The dealer is also required to state, for the coal he proposes to furnish, the percentage of fines or dust passing a

screen having circular perforations $\frac{1}{4}$ inch in diameter, and if this standard is exceeded by 5 per cent. in the coal as delivered, the excess per cent. above that amount allowed is penalized in proportion to the cost of the coal and the estimated damage caused by the fine material by choking the draft, etc.

This specification is intended to keep the cost of evaporating 1 000 pounds of water a constant in any given plant in spite of normal variations in the quality of the coal, and it is said to have accomplished this purpose very satisfactorily in the purchase of more than a million tons of coal, including most of the well-known varieties used in the eastern and central states.

The principle according to which deductions are made is that, in order to hold in court, the penalty exacted for inferior quality must only offset the damage sustained and must not constitute a source of profit to the consumer. It is also considered that the calorific value of the combustible portion of the coal from any given mine is a constant and that the correction for 1 per cent. of ash varies in different coals from 150 to 200 B.t.u. per pound.

In another form of specification the purchaser fixes an approximate analysis and a standard of heat units, allowing premiums and deductions at a fixed rate, generally 1 to $1\frac{1}{2}$ cents per ton for each 50 B.t.u. per pound determined by calorimeter test above or below this standard of heating value. This rate should be proportionate to the cost of the heat units determined by the contract standard and the price per ton bid. Ash above a certain percentage, generally 8 or 9 per cent., is penalized, generally at the rate of 1 cent per ton for each $\frac{1}{2}$ per cent. or fraction thereof in the dry coal in excess of the maximum allowed without deduction.

The approximate analysis for the better grades of steam coal sold in New England should be about as follows:

	Per Cent.		Per Cent.
Ash	5 to 9	Sulphur	0.6 to 2
Moisture	1 to 4	B.t.u. in dry coal	14 200 to 15 000
Volatile	16 to 23		

When the coal is paid for on delivery weights, the B.t.u. in the coal as received forms an equitable basis of settlement, as it corrects for moisture.

Where the bill of lading weights govern settlements, the average

moisture of coal in the mine or on cars at the weighing point, if this can be ascertained, may be used as a constant, but if the contract covers an entire year's delivery, as the variations in moisture in the coal as received will probably balance very nearly, no injustice would be done to either party if adjustment for quality were made on the *as received* basis.

Sometimes the dry coal basis is used in making corrections for heating value and the moisture is allowed for separately by subtracting from the weight of coal paid for the excess above a fixed maximum.

In most cases it is best to let the dealer establish a standard of quality for the coal which he proposes to furnish, but where several plants under the same management and at considerable distances apart are to be supplied with coal under the same specification by different dealers, who may be unable to supply the same kind of coal at all times, the problem becomes more complicated and it will probably cause less confusion if the consumer sets the standard, provided it is established with good judgment after having carefully considered all the circumstances of the case.

A committee of sixty-seven members of the American Society for Testing Materials has been appointed and now has under consideration the subject of coal specification with the object of standardizing as far as is practicable the requirements for different classes of coal. This committee has made a progress report, in which certain reforms regarded as desirable are outlined as follows:

(1) "A classsification of coals with respect to fuel efficiency, the adaptation of equipment to coals for obtaining the greatest efficiency from each class of these fuels, the continued use at each plant of that type of fuel best adapted to the equipment, the use of low-grade fuels either at the mine or within short distances and the use of the high-grade fuels under conditions demanding highest efficiency and requiring distant transportation."

(2) "Special efforts on the part of architects and engineers to provide everywhere adequate space for power and heating plants and proper equipment with a view to making the most efficient use of the fuels that are most available."

(3) "Such readjustment in the prices at the mines of the different classes of coal as will render possible clean and safe mining, and the use at local or distant points of all grades of coal worthy of being placed on the fuel list."

W. W. Polakov, in an article in the *Engineering Magazine*, has divided into stages all the operations from purchasing the coal to the final result of useful work done by the engine, giving to each stage a calculated efficiency.

For a typical case of a pumping engine he gives the following figures:

Stage.	Efficiency. Per Cent.
Purchasing coal	67.77
Combustion of coal on grates	90.10
Utilization of heat for generating steam	86.28
Utilization of steam in engine	82.20
Utilization of mechanical energy of the engine for pumping	89.11
Resultant total efficiency	38.59

The first three steps may be used to compare different coals, the efficiency of the steps being determined in the following manner:

First. The efficiency of payment. Obtained by comparing the actual cost of 1 000 000 B.t.u. in the coal under consideration with a standard price for which the same quantity of heat units could be purchased in the same market. In estimating the price, the cost of additional freight, handling, removal of ashes, etc., consequent upon the average percentage of ash in the coal it is proposed to purchase should be taken into account.

Second. Efficiency of combustion, which is the combustible actually used divided by the combustible available. This is determined by a boiler test, taking account of the amount of combustible in the refuse from the ash pit.

Third. Efficiency of utilization of the products of combustion. Found by dividing the heat absorbed per pound of combustible by the thermal value of one pound of combustible. This also requires a boiler test and calorimeter determination of the heating power of the coal.

The total efficiency is found by the formula $\mathrm{E}_t = \frac{E_1 \times E_2 \times E_3}{10\,000}$,

in which E_1, E_2, E_3 respectively represent the efficiency of the three stages.

While this method may be useful in comparing coals, it is not suitable for determining the value of coal as delivered in regular operation.

The foregoing specifications and tests apply to semi-bituminous and bituminous steaming coals. Anthracite coal is commonly purchased under a much simpler specification based on the percentage of ash alone, or sometimes on ash, moisture, and sulphur, with an allowable maximum for each, and penalties and premiums based on the price per ton.

It is probably impracticable to buy the buckwheat sizes of anthracite under a penalty and premium specification, for the price of these coals at the mine is low and the margin of profit is so small that it is entirely wiped out by even a small deduction from the selling price. The dealer to make himself safe will, therefore, bid so high a price that the use of such coal offers no advantage to the consumer.

It is unfortunate that there is at present so much confusion in regard to specifications, and it is to be hoped that the committee of the American Society for Testing Materials will be able to devise requirements which will result in uniformity of specifications for the different classes of coal as far as is practicable. Such a standardization is greatly to be desired, as there is no doubt that this method of purchasing coal has decided advantages to both parties, if the contract is properly made, and that it also has a marked tendency to raise the quality of coal offered for sale.

DISCUSSION.

Mr. Harry L. Thomas.* Would it be reasonable to expect to obtain a uniform grade of anthracite coal by continually buying from the same mine? For instance; if a carload of coal proved to be well suited to the needs of a gas producer, would there be any reasonable chance of getting the same grade by telling the dealer that we wanted more from the same mine?

Mr. Doane. I should say you would stand more chance that way than any other, but you could not be absolutely sure. If the dealer had any way of making sure that he did get coal from the same mine, I should think you would be fairly sure of getting the

* Assistant Superintendent Water Works, Hingham, Mass.

same quality of coal, but the way the dealers are fixed around here, it does not seem to be practicable to do that. We find, even when dealing with the largest dealers, that we get quite a large variation in the coal at different times, even when we try as hard as we can to get the same kind.

From our experience I should think it would be very difficult indeed to be sure of getting the same coal. You might get a few carloads which would be practically alike, and then an odd car would come in which would be quite different. Our experience has been, in buying pea and common-size anthracite coal, that it is hard to secure a uniform delivery. It may be, however, we are in a worse fix than you are, if you buy it in carload lots, because the anthracite we buy is generally for a station where the storage capacity is so small that the coal has to be delivered in cartloads.

Mr. A. S. Negus.* It has been my experience that the quality of coal varies with every different lot that you buy. If you buy a cargo, you are pretty apt to get nearly all one kind, but if you get another cargo you are likely to get something different; it may be a little better or it may be a good deal poorer.

Mr. Francis W. Dean.† I think that Mr. Doane has covered all of the points concerning the quality of coal, method of testing, etc., in a very admirable way. It seemed to me, as I followed his paper, that I should take exception to only one thing, possibly, and that is the method of testing coal by means of boiler tests. Generally speaking, I think that a boiler test is a very unsatisfactory method of determining relative values of boilers or of fuel, chiefly because different firemen can produce such different results with the same boiler and the same fuel. I must admit, however, that this can be done, usually, better at water-works plants than elsewhere, especially with twenty-four-hour service. At such plants there is usually a considerable ambition to produce good results, and the best methods of obtaining those results are studied.

Some years ago, I made some tests of a high-class locomotive type boiler at the Lynn Water Works, with at first very discouraging results. The boiler was put in with a remarkable high guarantee, viz., that it would evaporate 12 pounds of water per pound of

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† Mill Engineer and Architect, Boston, Mass.

combustible from and at 212° F. The result obtained on this test, instead of being 12 pounds or more, was 8.34 pounds. After putting in a new grate we obtained 9.54. I then changed firemen, selecting a man whom I knew could produce good results, and obtained on a preliminary trial 12.84 and on the final trial 12.04. After the second trial I had the gases analyzed and it was found that there was considerable carbonic oxide formed and an unusually large amount of carbonic acid, but that there was no free oxygen present. It is probable that hydrocarbons were being distilled from the coal and going up the chimney. This, of course, could not be detected by the ordinary gas-analyzing apparatus.

In regard to a question which one gentleman has asked about getting the same quality of coal in different cargoes, it seems to me that if you consider the fact that coal from the same mine comes from different veins, it is hardly likely that the same quality will be obtained in different cargoes, or perhaps in different parts of the same cargo.

Mr. Doane. I would say in reply to what Mr. Dean has said, that I tried to make it clear in the paper that I did not have a great deal of faith in the boiler test, and that it was simply one element in arriving at a decision. That is, taking into consideration the calorimeter test and the chemical analyses, I said that you could derive certain information from a boiler test, besides the efficiency of the coal in evaporating the water, which was valuable, namely, the amount and kind of clinkers you were liable to get, the character of the ash, whether the coal smoked badly or not, and other information of that nature, all of which are important considerations in settling the question of what coal to buy. I know that what Mr. Dean has said about the boiler test is very true.

Mr. Dean. Different kinds of boilers have to be fired differently. It has come to me to design and test a good many vertical boilers of late years. A vertical boiler is not generally approved of, but I think that is due to want of familiarity, although it is a fact that a vertical boiler has to be fired differently from other boilers. I think that a boiler that has a horizontal flame and an opening through the door, so you can let air through it, is, with careless firing, more apt to give good results than a vertical boiler, because

the air will go where it is needed, mix in, and produce better combustion than it will in the other case. But if the vertical boiler is fired properly, so as to get a proper amount of air in, you will get better economy. I think Mr. Doane has found that it does not make much difference at Chestnut Hill whether they run the Belpaire boiler, the vertical boiler, or the horizontal return tubular; they get about the same duty all the time.

Mr. Doane. I am rather inclined to think that while the difference is not great, it would be about in this order: The Belpaire first, the vertical boiler next, and the horizontal tubular rather a poor third. I think there isn't a great deal of difference between the vertical boiler and the Belpaire, both giving very satisfactory evaporation. I think I should have no doubt that with our firemen, we could fill the Lynn guarantee all right with either one of them, that is, 12 pounds, or better, from and at 212° per pound of combustible, because we frequently do 10 or better with a mixture of soft coal and anthracite screenings, or buckwheat.

Mr. Dean. Do you analyze the gases?

Mr. Doane. We do not analyze the gases as a regular thing, though we have some thought of putting in some form of CO_2 recorder. It is, of course, a question whether either one of the plants taken separately is large enough to warrant it, but as we propose to enlarge the plant considerably at the low-service pumping station, it may be advantageous to put one in. I think for large plants such records are of great advantage, principally because they furnish a means of keeping tally on the work that the different firemen do. If one fireman can do a little better on his watch than another, you have something really definite and tangible with which to show the man on the other watch that this first man is doing a great deal better than he is. As has been pointed out many times, these recorders do not save anything themselves. It is only their indications which are of value, and they are of no value unless they are acted upon.

Mr. Dean. Mr. Doane's experience with reference to the relative economy of boilers agrees with what I have concluded to be the case from tests I have made; that is, I have always got better results from the locomotive type of boiler than from any other.

Mr. Harry L. Thomas. Let me relate an experience. We purchased a carload of anthracite pea coal which proved so high in sulphur that it was entirely useless for our producer and we disposed of it for domestic use. A second carload, purchased with no more stipulations regarding efficiency or composition than applied to the first lot, proved excellent for our use; the engine ran continuously with no perceptible variation of speed or adjustment. The third purchase, made under the same conditions as far as we were concerned, and with the hope that we had found just what we needed, brought us coal that we are able to burn, but with very indifferent results. In the light of this experience I am anxious to know if there is anything practical which we can do, after having obtained a good coal, to establish it as a standard upon which to base future purchases. The coal was purchased directly from the mines in all cases.

Mr. Doane. Some pea coal, delivered from the mine, comes from the screenings where the coal is divided into sizes at the breakers; and other pea coal is washed out of the culm, or waste piles. Such coal is liable to contain a very large amount of fine slate and all sorts of dirt. It looks a good deal like coal when you see it, but it is quite different when you come to burn it.

Mr. Thomas. The trouble with the coal that we could not use was that it was very high in sulphur.

Mr. Doane. I was going to suggest that probably the sulphur might be a large item; it is probably a combination of sulphur and ash, one or both. I should think where you buy the coal a carload at a time it would be feasible, when you get a very good carload, to have that carefully tested. It would not be a very expensive operation, probably between \$15 and \$20. You would probably want the sulphur, ash, and British thermal units determined — there isn't much volatile matter in anthracite coal. But it would be valuable information to refer to, and from it you could make some kind of an arrangement with your dealer so that if you got another carload that was unsatisfactory you could have an analysis made of that, and, if it wasn't reasonably near the results of the test on the good coal, the coal might be either rejected or bought at a greatly reduced rate.

Mr. Thomas. One lot of coal we used was analyzed before we

used it, and while the analysis showed the British thermal units to be very satisfactory in number, it was rather indifferent coal for us to use. This test was not of so much consequence as the sulphur and ash.

Mr. Doane. The British thermal units and the ash will probably vary pretty nearly in inverse ratio, but the sulphur, of course, is an element which would be variable, and I should imagine in a producer plant the coal perhaps wouldn't have to vary a great deal in ash and sulphur to be either quite bad or very good.

Mr. Thomas. That is the point. It is either one or the other.

Mr. Doane. You have got a pretty narrow margin, you see, and you are probably worse off than a person burning it under a boiler would be.

Mr. F. S. Hollis.* I should think that chemical analysis would be of the greatest value in the determination of the relative value of different lots of the smaller grade of anthracite coal.

A partial analysis, consisting of the determination of the loss of weight on burning, representing carbon and volatile matter and of the ash, ought to serve pretty well in determining the value of the coal for steam production. In case it is to be used in a producer the determination of sulphur and an idea of the character of the ash is, as Mr. Doane says, of much importance and should be included in even a partial analysis of a coal for that purpose.

Mr. Doane. I think in the case of a producer the sulphur would be of more importance than it would be if the coal was going to be burned to make steam, for the reason that in a producer, as I understand, — I am not very familiar with producer plants — the effects of variation, not only in the amount of ash, but in the quality of ash, are very material, so that a small variation in the amount of sulphur might change the ash from one which would be friable and easily gotten rid of to clinkers you can't get rid of, which almost completely stop the air from going through the fuel bed; consequently the gases given off are not of the right composition.

Mr. Thomas. That is precisely the difficulty.

Mr. Negus. Speaking of boilers and coal, my experience has been that there is a great deal more difference in the firemen hand-

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ling the coal than there is in the coal itself. If one fireman doesn't know what another uses, he will use more coal than he ought to.

It is claimed that there isn't much of any difference between the Belpaire and the vertical boiler, but I am not an advocate of the vertical boiler from what experience I have had. At New Bedford we had two vertical boilers of the Corliss type, with very little combustion space between the grate and the tube sheet, which I think was a great disadvantage. We had, and we have there now, one Belpaire boiler, which I think is one of the nicest boilers that is made. Using the two types of boilers with the same engine, doing exactly the same work for twenty-four hours, there will be 1 200 pounds of coal difference. You might take three firemen and have them on eight-hour shifts, and not let one know what the others were burning, and they would run over what they actually ought to use from 100 to 200 pounds in an eight-hour shift.

I am sorry Mr. Dean has gone, because I was going to ask him to give us a few points with regard to vertical boilers. He is designing one very large boiler, and I have always been of the opinion that if there was sufficient space between the grate and the tube sheet they would perhaps do a great deal better, but we have had very poor luck with them down our way compared with other boilers.

Some years we have one grade of coal and some years another, but we don't find such a very great difference; but we do find a lot of difference in the men who handle it. Of course, when we get Georges Creek coal it requires a little more work to fire it and get as much economy out of it as you get out of some freer burning coal, or something which doesn't have to be broken up as much. We use anything which comes along, whether it is Georges Creek, New River, or Pocahontas, or whatever it is, and we don't find such a great deal of difference. One burns just about as well as the other, only one requires a little more labor than the other. The gentleman was speaking about the use of pea coal, and I will say that we burned pea coal at one time and we found that with some kinds of treatment we could get along very well with it, particularly if we kept an extremely thin fire. So I think in many cases where they have trouble it is due to the kind of use it has more than it is to the quality of coal.

Mr. Doane. I will say that the question Mr. Negus has just raised as to the height of the tube sheet from the fire or grate in vertical boilers is the vital point in the design of vertical boilers; also, that coal high in volatile matter is not suitable for vertical boilers. Anthracite coal probably is the most efficient for a vertical boiler, but coal quite high in volatile matter can be burned if you have the right proportion between the height of furnace and the length of tubes.

Mr. Edward D. Eldredge.* Reference has been made to mixing anthracite screenings with bituminous coal. I should like to ask Mr. Doane if he considers that a point of economy to any extent?

Mr. Doane. We consider it economical in our work and we use as high as 50 per cent. screenings. There is a certain percentage at which the cost of pumping 1 000 000 gallons begins to increase, and we stop short of that. Our records are kept in such a way that we can tell whether we are gaining or losing by using different mixtures, and we use the mixture which seems most suitable, which, we find, varies with the load. When the boilers are being forced you cannot use as large a percentage of screenings as you can when you are going along easily, so we have to proportion the mixture to the requirements of operation at the particular time. But we do find that there is a material saving in burning it. The price, of course, has to be carefully looked into, for it does not pay to burn fine anthracite which costs above a certain price, and it does not pay to use over a certain amount in the mixture. With forced draft and proper equipment, of course a good many plants use it altogether, with no bituminous at all, but we are not equipped to burn it that way. It requires, also, a greater boiler capacity, even with the best equipment, because it has not got the heat units in it, and no matter what your equipment is, you can't get more heat out of it than there is in it. In general you will find you will have to increase your boiler equipment in order to burn it satisfactorily, and that it requires a lot more labor to fire it properly.

* Superintendent of the Onset Water Company.

THE MAIDSTONE TYPHOID EPIDEMIC.

BY WILLIAM P. MASON, PROFESSOR OF CHEMISTRY, RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.

[*Read January 12, 1910.*]

In 1897 the county town of Kent, with a population of 34 000, was visited by a serious outbreak of typhoid fever, and, although in a general way we on this side of the Atlantic have had some information concerning the epidemic, yet no special presentation has been made to an American audience of the interesting features of the case. During a recent visit to the spot the writer has been enabled to secure data for the following sketch. Full use has also been made of the official report, and its illustrations.

Maidstone is situated upon the Medway River, but the water with which the town was supplied came from underground sources, being developments of a number of local springs so situated as to be utilized in three several groups. It was one only of these groups that had its water infected, and the cause of such infection is the interesting point in the case.

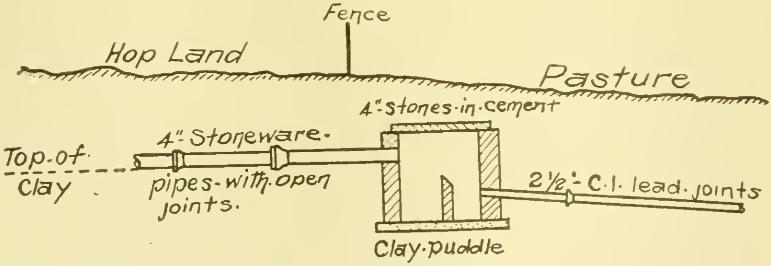

FIG. 1. CROSS-SECTION SHOWING COLLECTING DEVICE.

The present municipal supply is derived from deep wells and from galleries driven into the chalk along the plane of its junction with the underlying clay (Fig. 1), and the water so secured is excellent, but our interest is centered in the conditions as they existed in the summer of 1897.

At that time the city's water was obtained from the subsoil

drainage of a highly cultivated district where the soil is often of stiff clay, capable of ready desiccation, with formation of deep soil-cracks during periods of little rain. Through such a dried and fissured soil water can pass rapidly, and in relatively large streamlets, without securing the full advantages of efficient filtration.

A glance at the illustrations is sufficient to show that plenty of opportunity would be given for such polluting material as might be thrown upon the ground surface to pass the arable layer in times of relative dryness and reach the tile collectors resting upon the clay bed a few feet below. As to what kind of pollution might occur upon such surface, let it be said that the whole district is heavily tilled and, consequently, manured, and that the staple is "hops," a crop whose method of harvesting presents conditions both peculiar and dangerous.

Hops ripen at Maidstone in the latter part of August, and the crop is gathered by a small army of "pickers" recruited from the slums of London. During the picking season these people come down in families and settle temporarily upon the land, a large number of them living in the open, covered by whatever shelter can be secured. They are paid at the rate of one shilling for seven "baskets," an amount equal to sixty imperial gallons all told. Usually a family, children included, are assigned a "bin," which is a vessel made of sacking 8 x 2½ x 2½ feet in dimensions, and into this their pick is thrown. The green hops are placed upon the perforated floor of a "drier" in a layer 2 feet deep and are heated by a small coal fire, upon which is thrown about five pounds of sulphur, the fumes from which kill all insects that may be present, and when dried the hops are pressed into bags for market.

It is a matter of common knowledge that land containing much clay will, under the influence of summer sun, become deeply fissured provided that no rain falls to neutralize the drying effect.

From the character of the Maidstone "pickers" it is easy to conceive that typhoid might be carried to the hop-fields, and, if so carried, abundant opportunity would be given for infection to pass into the local ground water during periods of drought. Dejecta deposited upon the surface would surely be washed by the first rain into the deep cracks formed in the clay soil through the influence of desiccation.

Fig. 1.

Fig. 2.

The Hop Pickers' Camp.

In 1897 the cracks in the Maidstone soil were well developed because " from June 29 to August 6 there had been no rain save on July 26 and 27," and then only 0.21 inch. It is easy to see how any polluting material deposited upon the surface, whether by the hop-pickers or others, could thus pass easily into the substrata without undergoing purification by soil percolation.

Many of us will remember the relationship suggested by Pettenkofer as existing between low ground water and typhoid fever, and the still more interesting work of the Michigan Board of Health, showing that the increase of the disease synchronized with the rise of ground water level caused by the first heavy rain following long drought.

The Maidstone experience accorded with the " Michigan rule." Heavy rain fell on August 7 and 8, the ground water level rose rapidly, and two weeks later the typhoid epidemic began. Dr. M. A. Adams pointed out that the sudden high water level was due " to the highly desiccated clay being unable to readily absorb so much moisture." Later, however, " notwithstanding occasional rainfall," the water level began to decline because of increased power of absorption on the part of the soil, and subsequently the heavy rains of the end of August caused a second rise of ground water, which, allowing for the two week's incubation period, corresponded with the climax of the epidemic. Dr. Adams shows in illustration a sketch (Fig. 2) in support of his view as to the cause of the epidemic, and pictures the deep soil cracks which he observed in the hop-lands.

It is interesting to observe the relation of the outbreak of typhoid to the rise in ground water as shown by chart in the report of the Local Government Board, although it must be admitted that the data call for a very short incubation period if we are to assign the disease to the hop-pickers as a cause. The same report also pictures in chart form the epidemic of severe " diarrhea of a somewhat peculiar kind " which preceded the typhoid and more nearly synchronized with the rainfall.

Many observers have noted and reported this tendency of typhoid epidemics to be immediately preceded by diarrheal disturbances. Whether or not the typhoid was in this instance due to pollution carried to the locality by the London pickers, or to

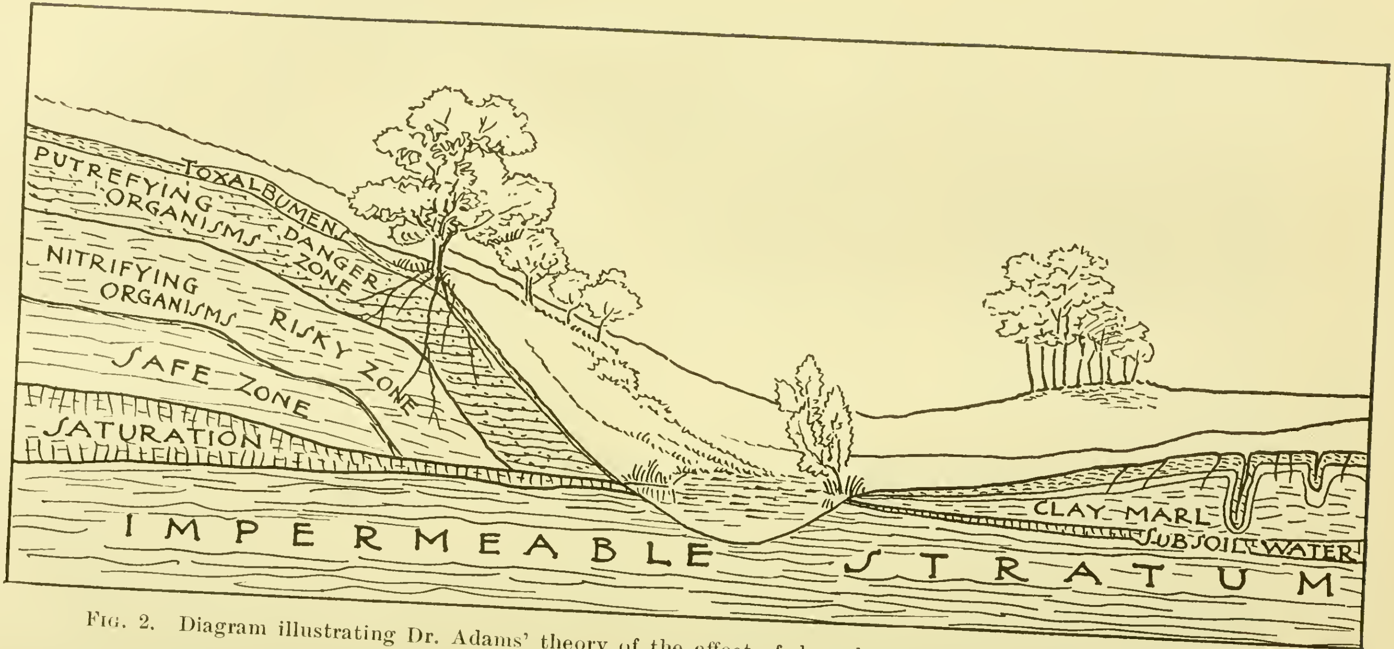

FIG. 2. Diagram illustrating Dr. Adams' theory of the effect of drought on clay in relation to water supplies.

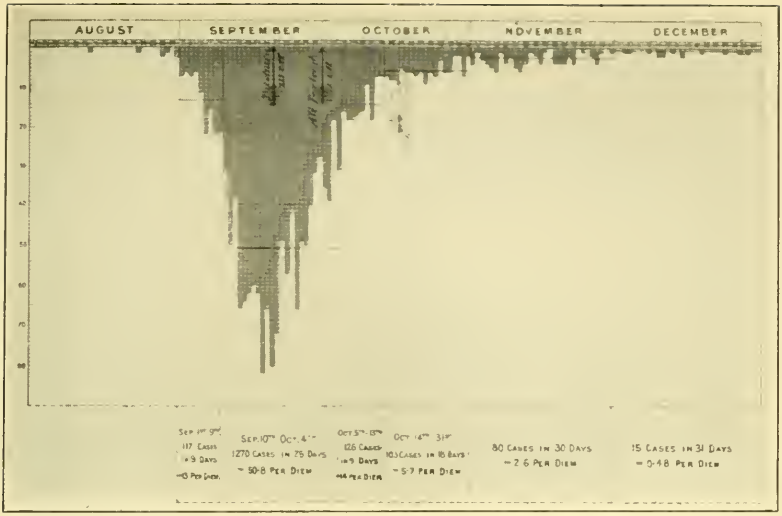

Fig. 1. Showing day by day the number of persons known to have been attacked by enteric fever in Maidstone. The arrows show the dates when the Tutsham and Farleigh supplies were cut off and when the mains were disinfected.

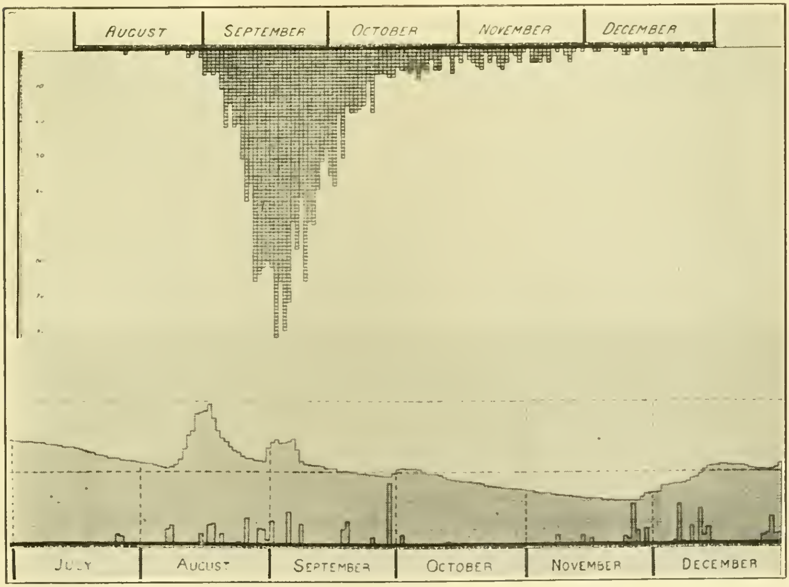

Fig. 2. Showing diagram of Fig. 1 compared with the amounts of daily rainfall (in inches) (shown at the bottom), and the variations in level of the subsoil water (in feet).

similar material of local origin, or to "the very highly and deeply manured soil of the hop gardens," the lesson for us lies in the manifest relation existing between a polluted surface soil and the underlying ground water when the former becomes dry and fissured by prolonged drought.

In view of the present interest taken in the hypochlorites for use in water purification, let it be said that subsequent to cutting off the infected water, the mains at Maidstone were flushed with a solution of "chloride of lime." The result so far as disinfection went was satisfactory, but we now know that the "dose" used was far larger than was necessary.

No less than 583 grains of "bleaching powder" per United States gallon of water (equivalent to 204 grains of available chlorine), in other words, a 1 per cent. solution, was the strength proposed for employment, but even this enormous dose was exceeded through an oversight, and the solution actually used was still stronger. It is not surprising, therefore, to learn that "nearly every tap started leaking and had to be re-leathered" and that "the fire-engine, pump-buckets, and delivery and suction hose were entirely destroyed." From our present knowledge of the very minute dose of "bleach" that will kill intestinal organisms, we are perfectly willing to endorse the belief of the Maidstone authorities that "no microörganisms of any form that could have obtained access to these pipes could remain alive and active."

DISCUSSION.

Mr. R. S. Weston.* Mr. President: It is rather interesting, I think, that while the Germans have been accustomed to consider ground water supplies absolutely safeguarded against pollution of all kinds, this English epidemic should have occurred to illustrate the great differences in ground-water supplies. Ground-water supplies which are drawn from sand, especially from large areas of fine sand, which removes the effects of all surface pollution, illustrate one type, and those which are from limestone rock full of caverns and fissures, or from the chalk, as in the Maidstone case, represent another type. We should be very careful, therefore, before laying down any absolute and fixed rule regarding the

* Consulting Engineer, Boston, Mass.

safety, or lack of safety, of any one class of water supplies, for while ground-water supplies possess great advantages, and are usually much safer than a surface water source, there are cases, as at Maidstone, where they are subject to more sudden and more extensive pollution than even some of the worst surface water supplies, for the reason that when a well does get polluted, it requires a very much longer time for the pollution to pass away than in the case of many surface supplies.

Dr. Mason. Mr. President, may I say just one word as illustrating what people will do when they are badly frightened. When I was over there a little while ago they told me in Maidstone that their reservoir has a few pipes opening into the open, and that those pipes were now plugged with sterilized cotton.

DEPRECIATION IN WATER-WORKS ACCOUNTS. WITH REFERENCE TO UNIFORM REPORTS.

BY HARVEY S. CHASE, CERTIFIED PUBLIC ACCOUNTANT, BOSTON, MASS.

[*Read February 9, 1910.*]

Some twenty years ago the writer was superintendent of a water works in one of the smaller cities of New England, and subquently became treasurer, and was also manager of the gas plant in the same municipality. During his administration the water works were rebuilt, new pumps were installed, a water tower erected, a filter introduced, and the mains extended in many streets. At the same time a complete reorganization of the gas plant went on, with new works and holders. The process was changed from coal gas to water gas, and the mains throughout the town were repaired and relaid. This was the first practical experience with questions of depreciation on a considerable scale with which the writer had to do, for, as may be surmised, no allowances for depreciation had ever been made in the accounts of the water works or of the gas works prior to that time. All these renewals and reconstructions required the investment of new capital for the time being, although this was ultimately made up out of earnings in subsequent years.

From that time questions relating to depreciation in public service corporations and in municipal industries have played a prominent part in the writer's experience, as he has been engaged as an expert witness in a number of important suits relating to water works, gas plants, and electric light works in which the determination of fair rates for depreciation was fundamental. In each case, in fact, the result of the suit depended almost wholly upon a correct setting forth of these matters. The Holyoke Water Power case was one of these suits. Boston Consolidated Gas Company, Haverhill Gas Light Company, Norwich Gas and Electric Company were others.

Having been called upon in a professional capacity to reorganize

the accounts of various municipalities during the past ten years, the accounting of public water works and electric light works has been drawn forcibly to the writer's attention. Moreover, as chairman of a committee of the American Association of Public Accountants which has reported upon questions pertaining to uniform accounts in public service corporations and in municipal industries, the necessity for correct accounting of depreciation has been further impressed upon him. The reports of this committee may be found, by those interested, in the Proceedings of the American Association of Accountants for past years.

In connection with the Bureau of the Census, special attention has been given by the writer to water-works accounts, while in 1907 a report was submitted by him to the New England Telephone and Telegraph Company which pertained especially to depreciation and kindred questions in the telephone field. These matters have been mentioned here in order to show how wide a field, in the experiences of public accountants as well as of water-works, gas, and electric engineers, is covered by matters related to depreciation.

Mr. Albert H. Wehr, at the annual convention of the American Water Works Association last June, presented an admirable paper relating to uniformity in the accounts and reports of water works, in which he refers to the recent work of the United States Census Bureau and to the conclusions of Dr. Powers of the Census in the Bureau's bulletin, "Statistics of Cities," published early in 1909.

It may be advisable for me to summarize the statements of Mr. Wehr and Dr. Powers before proceeding to my own conclusions concerning the subject of this paper.

Mr. Wehr's considerations in favor of a uniform classification of accounts are as follows:

"The evolving of any uniform classification of accounts for water supply or any other form of public service enterprise must be based on certain considerations of purely practical utility, of which the five following are the most important, viz.:

"1. To afford managers such detailed information relative to the operation of their properties as to enable the making of careful analyses of income and expense, both separately and as compared with previous similar periods.

"2. To afford accurate comparability of the operating results of such enterprises with those of any other similar enterprise.

"3. To so divide and subdivide the expenses as to easily enable the ascertainment of the separate and distinct elements of cost which make up the total cost of service. . . .

"4. To so devise the scope of the classification as to place the enterprise, whether privately or municipally owned and operated, on a basis which will disclose all income earned by the enterprise, whether actually received or not, and show the actual expense of operation or cost of service, whether actually paid or not.

"5. To so devise the classification as to divide the various branches or departments of such classification into certain fixed and clearly defined centers of division, from which all subdivisions radiate. . . ."

In this connection, Mr. Wehr has devised a scheme of enumeration for the classified accounts which is simple, effective, and cleverly arranged. Mr. Wehr's paper sets forth definitions of the classifications, following in the main the terms accepted by the Census Bureau, and gives a complete scheme of the classified accounts under these heads:

1. Income Accounts.
2. Expense Accounts.
3. Allocation and Profit and Loss Accounts.
4. Outlay, or Property Accounts.
5. Asset Accounts.
6. Liability Accounts.
7. Proprietary Interests, or Proprietorship.

In this classification *depreciation* appears under various headings, the first of which is 214, "Expenses for General Depreciation," with subdivisions as follows:

2140. Undistributed Expenses for General Depreciation.
2141. Depreciation of Administrative Property.
2142. Depreciation of Accounting and Commercial Property.
2143. Depreciation of General Operating Property.

Also under the heading 224, "Expenses for Water Service Depreciation," appear the following subdivisions:

2240. Undistributed Expenses for Water Service Depreciation.
2241. Depreciation on Sources of Supply Property.
2242. Depreciation on Intakes and Aqueducts.
2243. Depreciation on Purification System.
2244. Depreciation on Pumping Station.

2245. Depreciation on Transmission and Distribution Storage System.

2246. Depreciation on Distribution System.

2247. Amortization of Preliminary Expenditures.

And under 23, "Miscellaneous Expenses," appear

23115. Depreciation on Tools and Appliances — Plumbing.

23125. Depreciation on Buildings, Tools, and Appliances — Shops.

23136. Depreciation on Buildings, Teams, and Equipment — Stables.

23144. Depreciation of Rental Property.

23155. Depreciation on Tools and Appliances — Meters.

23164. Depreciation of Forest Lands and Reservations.

23174. Depreciation of Other Accessory Enterprises.

Under 232, "Expenses of Invested Funds," there is an item 2322, "Expenses of Depreciation Funds"; also 325, "Depreciation in Invested Funds Values"; and 342, "Depreciation and Amortization Funds." Among the assets under the general heading 5 appears 563, "Depreciation and Amortization Funds."

No accounts appear among the liabilities under general heading 6, where we should expect to find "Depreciation Reserves." This fact particularly appeals to me, as it is the special point on which I must criticise the otherwise admirable and exhaustive classification of Mr. Wehr. No explanations of Mr. Wehr's views concerning depreciation reserves appear in the text of his paper, but in the Census Bulletin, on page 334, the term "depreciation" is defined as given below. In the Census classification, depreciation accounts appear under the following headings:

VII. Expenses for Water Service Depreciation.

208. On General Administrations Buildings and Equipment.

209. On Accounting Equipment.

210. On Operating Management Buildings and Equipment.

211. On Sources of Supply.

212. On Intakes and Aqueducts.

213. On Purification System.

214. On Pumping System.

215. On Transmission and Distribution Storage System.

216. On Distribution System.

There are also accounts for depreciation of pumping, rental property, meters, stables, etc., these being in accord with Mr. Wehr's classification. The Census definition of depreciation is as follows:

" *Depreciation.* Depreciation is a general designation of the gradual diminution in value which is caused by wear, decay, displacement, or obsolescence in the value of buildings and equipment, and of the sudden diminution which results from fire or other destructive forces. It is never actually or relatively the same for any two establishments, even of the same industry. For this reason it is impossible to frame concise, general rules for making allowances for depreciation which will not in their application be attended with a large margin of possible error. To use such rules without causing errors, those employing them must have for each individual establishment exact data based upon inspection, showing how far and in what respects its actual depreciation differs from that of the average establishment of its class. For this reason, a physical examination and appraisal of water works should be made every ten years, or even more frequently, in order to provide the basis for an approximate statement of the annual loss chargeable, as an expense, to depreciation. In the absence of such exact data for each water-supply system, however, it is to be assumed that depreciation takes place according to the average life of the several parts of such a system and of water-supply plants as a whole. The knowledge at the command of the Bureau of the Census leads to the conclusion that this average life is approximately as follows: For horses, carriages, automobiles, and laboratory fixtures and meters, ten years; office furniture and general equipment, fifteen years; boilers, steam pipes, and filtration equipment, twenty years; engines, pumping machinery, and wood pipes, twenty-five years; masonry of filtration plant, cribs, iron water pipes, intake pipes, fire hydrants, standpipes, and buildings, fifty years; reservoirs, tunnels, and aqueducts, one hundred years; and for the water system as a whole, fifty years.

" There are many methods which may be employed in the computation of depreciation from data such as are above referred to, all of which involve the assumption that depreciation proceeds either with a uniform or with a geometrically accelerated rate

throughout the life of the plant or fixture. The actual rate of depreciation unquestionably increases geometrically, and for this reason the best method of computing the amount of depreciation which has taken place during a series of years, or during a particular year, is that which is sometimes called the sinking fund or compound annuity method. The depreciation during the first year of any property having an expected life of fifty years is represented by a quantity equal to the annual payment which would have to be made each year during the fifty years, and invested at some specified rate of interest, to amount at the expiration of the fifty years to a sum equal to the original value of the property. The depreciation for any subsequent year would be the same quantity plus an amount equal to the interest on the prior payments and accumulated interest earnings at the specified rate. . . . By means of tables and diagrams, the depreciation for each particular portion of the water-supply system can be computed for any given year of its life, and thus the total depreciation for the system be ascertained, provided the enterprise has a detailed statement of its property and equipment as explained later under ‘ tentative instructions for accounts, with cost and present value ’; and, provided further, that the probable life of each division of the system has been ascertained by physical inspection, and that the rate of depreciation has also been determined in the same manner. The depreciation taking place in the water-service system in a given year, calculated as above, should be charged as an expense in primary accounts 208 to 216. This depreciation, however, is primarily an entry in the accounts with property and equipment, as shown in the accompanying summary of the cost and value of the water supply system and of its extensions, additions, and renewals. When detailed data are lacking for computing depreciation as outlined above, it may be assumed that the aggregate depreciation to be included in the accounts mentioned, or in subgeneral account VII, is 2 per cent. of the present value of the water system. . . .”

The Census classification for water-works accounts does not set up a complete balance sheet of assets and liabilities, nor does it give a detailed list of liability accounts, in which should appear,

according to the writer's opinion, a series of depreciation reserve accounts. It is owing to this omission, both in the Census classification and in Mr. Wehr's, that the present paper has been written, and the writer will, therefore, give a brief explanation of his reasons for urging the inclusion of depreciation reserves in all such classifications.

Much experience under the conditions in which public service corporations are acting in most municipalities convinces the writer that it is fundamentally necessary that questions of depreciation should be carefully considered, accurately worked out, and regularly entered upon the books of all such corporations. This being the case in private works, it is also necessary that municipally managed public services should have similar accounts. The reason in both cases is the same, viz., in order that *fair* rates may be established, that is, rates which will be just to the consumers and also fair to the plant. Such rates cannot be just unless full allowances shall have been made for deterioration of the plant, or, in other words, for the capital losses which arise from depreciation. Such losses must be provided from income, or otherwise they will require new capital. Therefore, they should be handled in the accounts as regular charges against income. This is most forcibly true in all plants which have to do with electricity, for in such plants depreciation during past years has been rapid, and changes in the art have frequently demanded that machinery should be scrapped even though the machines themselves might be in excellent physical condition. Electric street railway companies, electric lighting companies, and telephone companies are fast coming to see the necessity for proper and complete provisions for depreciation. Gas companies are next in importance in this particular, while water works may be considered last. It must be noted that it is frequently the fact that "appreciation" in the general value of any water works, due to increase of population in its territory, may offset in great part, and sometimes may even exceed, the losses by depreciation which occur during a given period. Therefore, while the emphasis which is here laid on depreciation accounting is accepted in full by electrical concerns to-day, and accepted in part by gas companies, it is nevertheless true that water works have not as a rule acknowledged

the necessity for such accounting, or, at least, have not adopted such accounts in their bookkeeping systems. The same arguments which have compelled the use of depreciation accounts in electrical concerns will, in my opinion, compel their use ultimately in water works. This will come about mainly through the instrumentality of state supervising boards, which will require uniform reports from all municipalities and from their departments, in which a water department is frequently included.

Just as the Gas Commissioners of Massachusetts have required definite allowances for depreciation in the accounting of municipally operated plants, so, in due time, similar requirements will be promulgated for municipal water works.

If the writer has stated the facts correctly, and if his deductions in regard to the future are true, it is evident that proper accounting for depreciation should be undertaken promptly in all such plants. The best way to handle these matters, in the writer's opinion, is by a series of *depreciation reserve* accounts, that is, by reserve accounts which correspond to the different classes of assets, and which appear in the balance sheet as liabilities (credit balances). Every monthly closing should provide for items to be charged to *expense* and at the same time credited to these various reserve accounts. Each of these charges should be based upon a carefully calculated percentage which will vary according to the estimated life of the particular class of asset. Whenever depreciation is made good by actual expenditure for renewals or reconstruction, such amounts should be charged against the corresponding depreciation reserves and thereby the balances remaining in these reserve accounts will show whether or not sufficient monthly allowances are being made year by year to provide for depreciation losses, shown by the actual expenditure for renewals and reconstructions. The necessity for depreciation reserve accounts being evident, the writer urges that particular attention be given to them in all public service accounting, and trusts that, in future editions of the Census classifications, statements of liability accounts will be included in which will be set forth in detail a depreciation reserve for each of the various classes of deteriorating assets.

If what he says here will, in some measure, bring the importance

of such reserves forcibly to the attention of practical bookkeepers and managers of public services, the writer will have accomplished all that was intended by the preparation of this paper.

DISCUSSION.

Mr. Harvey S. Chase. This question of depreciation in connection with public service corporations is, it seems to me, one of the most important questions which can be discussed. It happens that I have been called upon in litigation in connection with public service corporations in a number of different cities and towns in New England and elsewhere, and in every case that I remember the question of depreciation was a fundamental one, both in the matter of what are fair rates and in the problem of establishing a fair price for a municipality taking over a water works. In both those classes of cases, and those are the two which are the common ones in public service corporation litigation, and particularly in connection with gas and electric light plants, that has been the important point.

Three years ago, I think it was, we were called in by the New England Telephone and Telegraph Company to make an investigation of their bookkeeping, particularly with reference to depreciation. We endeavored to make a very thorough study of the situation there, because the question of rates with them, of course, is singularly important, as they cover such a large territory. Since that time the Highway Commission under the new law has taken charge of establishing rates and controlling the company in the same way that the Gas Commission controls the gas and electric light companies. At the time we made our investigation the telephone company had no depreciation reserve accounts, and it is on that subject that I should like to elaborate somewhat.

In any public service corporation, and more particularly in public service corporations where deterioration is rapid, this question of depreciation is very important. In all electric enterprises, — street railways, electric light plants, telephone and telegraph companies, — everything connected with electrical devices deteriorates rapidly, and, further, a very considerable amount of obsolescence ensues on account of the rapid development

of the art, so that machinery which was good at the time it was put in, and which has been in but a short time comparatively, may have to be thrown out, although its physical condition is excellent, because new machinery has been invented which must necessarily supersede the old. Now, unless provision is made in the accounts of corporations, public service corporations particularly, whereby these losses and costs from depreciation are paid out of income, there ensues naturally a capital loss. Either there must be sufficient income laid aside to provide for depreciation in all its forms, or we will have a shrinkage of capital. There can be no escape from that proposition.

Frequently we hear depreciation spoken of as if it were not an element of expense. It *is* an element of expense, just as much as salaries, supplies, wages, or any other element which we ordinarily charge to maintenance or operation of the plant. It is a fact, however, that it is much more difficult to provide for, and much more difficult to calculate, than are these items, and the only way in which satisfactory provisions for depreciation have been arranged in public service corporations to my knowledge is by the establishment of " depreciation reserve accounts."

I suppose the great majority of you know exactly what I mean by depreciation reserve accounts, but in order to make it clear to those who do not, I will endeavor to explain briefly and simply. Let us suppose that at the end of a month we are going to charge up against income all the expenses of that month. We charge, of course, for all the expenses of operation, for all the expenses of maintenance, and by " maintenance " I mean repairs of the plant, and *an estimated amount for depreciation.* Very few water works, I imagine, to-day make such a monthly charge for depreciation calculated in a scientific way. My contention is that we must all ultimately come to making exactly that charge for depreciation monthly in all accounts. We make that charge against income on the one side, and set it up in our account on the other side of our ledger as a credit to one or more depreciation reserve accounts. There should be, in my opinion, a depreciation reserve account for each of our different classes of assets.

Now we have made a charge against income in our account, calculated on the basis of percentages according to the life of the

different portions of our plant; we have set it up in a series of depreciation reserve accounts on the other side of our ledger; and we do that every month, thereby accumulating a series of credits standing in the ledger accounts. When we come to the question of renewals, which ordinarily on a cash basis we should charge against income, instead of charging it against income we charge it against one or the other of these depreciation reserve accounts. We have already charged income, you see, with the estimated amount of depreciation; now we charge against that depreciation reserve the actual costs of renewals. That is to say, when we make a renewal or reconstruction of pipe, we charge it against the depreciation for mains; when we make a renewal of plant, pumping plant or otherwise, we make it against the depreciation reserve for plant, for pumping plant, and so on down through the list.

While this matter is not so important in water works as it is in other classes of public service corporations, for the reason that deterioration does not go on so rapidly in water works as it does in the other public service corporations, it is still equally important when we come to discuss the question of what are fair rates for water works. We can all see that, if we have depreciation going on, as there frequently is in electrical concerns, amounting to 10 or 15 per cent. or more per annum, unless we provide for that carefully, so that our rates to consumers will allow us to lay aside moneys to make good that depreciation, we shall not be charging rates which are fair to the companies. Those rates must be so established as not to be below the point where proper depreciation can be taken care of. That is just as important in water works, in kind, though not in degree, as it is in telegraph companies, telephone companies, street railway companies, or gas and electric light plants.

The distinction between new construction, reconstruction, and ordinary repairs is one in which, I imagine, all of you gentlemen are more or less entangled. Everywhere I go I find that the managers of public service corporations are at a loss for a proper definition of what is "construction" (to be charged to assets to increase those assets), what is "reconstruction" or "renewals" (which should be charged against depreciation reserve),

and what are " ordinary repairs " (which should be charged against the income of the month, just as wages are). The distinction which is made in the big public service corporations between reconstruction and repairs is usually made in this way: Whenever a piece of work is big enough to justify an estimate beforehand, so that the exact cost of the reconstruction or renewal is to be estimated and passed upon by the officials before it is authorized, that is considered a reconstruction or renewal item and is charged against the depreciation reserve. All other items, which are simply passed upon in the ordinary course of business, without a requisition or appropriation beforehand, are considered as repair items and are charged to the ordinary monthly expense. That distinction, particularly when you are dealing with an electrical concern, is exceedingly important, and it is only a question of time when it is going to be equally important in water works. We can already see it in many places in the West. For instance, the city of Denver, which has private water works, is in discussion with the water company and is threatening to take over the works. The question of the depreciation of that plant, and the question of what is a fair price to be charged, are now under most searching investigation. And so it is in cases which have come up nearer home. I might refer to the Holyoke Electric Light and Gas case, with which you are familiar, which was settled wholly on the question of depreciation; to the Haverhill Gas Company case, which has been very prominent; to the Norwich case, the New York Consolidated Gas case, the Boston Consolidated Gas case, and so on. They all came down to this question of depreciation. And yet I venture to say that in the majority of the books of the corporations which you gentlemen administer there are no regular, scientifically estimated depreciation reserves, although doubtless there have been in a great many of your works careful provisions for depreciation.

But take private corporations, for instance, and how do they provide for depreciation to-day? The great majority of private corporations make no calculated provision for depreciation. In a good year, when they have made a great deal of money in excess of what they should distribute as dividends, they lay aside ten, twenty, thirty, or one hundred thousand dollars and call it a reserve

for depreciation, without any calculation or any knowledge on their part as to whether or not it is the right amount to lay aside; it is an amount that they have available, and they lay it aside. That may be very well in the case of a private corporation, a close corporation, where if they lose one year they make in another, but it will not do for a public service corporation which has its own relationship to the public, and whose rates are established by the character of the service and the cost of the service that it renders the public. A public service corporation is entirely different from a private corporation. The new corporation tax law which has been recently passed requires all corporations throughout the country to make careful provisions for depreciation and to state these provisions in their returns to the Internal Revenue officers, with the penalty that if they fail to make such provisions for depreciation and to deduct them from their income, they will have to pay a larger tax than they would otherwise pay. It seems to me, even if the corporation tax law should be declared unconstitutional, and should be thrown out, that the fact that it has brought to the attention of corporations throughout the country the necessity of providing for depreciation in their accounts, and setting it up intelligently on their books, will be worth all the cost of that act, both to the federal government and to the corporations themselves. There are a number of other provisions in that act which are, perhaps, equally as important, but that particular provision for depreciation is right on the line of our discussion.

In the last part of my paper the question of depreciation reserve accounts is considered, and comment is made upon the papers of Mr. Wehr, presented to the American Water Works Association, and upon the conclusions of Dr. Powers, which were published in the Census Bulletin "Statistics of Cities" early last year, in which you will find a number of depreciation accounts. In both cases depreciation is very well handled in these standard forms of accounts, as suggested by Dr. Powers and by Mr. Wehr, but it is handled only from the point of view of charging depreciation against income. There is no provision in either of these papers for establishing depreciation reserve accounts on the other side on the ledger, against which the actual money expenditures for renewals and reconstruction should be entered. This is the

point of my paper, and the point which I desire to bring to your attention to-day, — the necessity and advantage of establishing "depreciation reserves" which are credit accounts, and against which the actual renewals of the year should be charged, so that running over a period of time, say ten years, with such accounts it would be evident whether the total of your actual costs of renewals and reconstruction are the equivalent of the amounts which you have laid aside and regularly charged against income each month. By these regular charges against income each month, you get a true comparison month by month of the costs of running your works. If, on the other hand, as is frequently the custom, the amounts of renewals and reconstruction are charged against income whenever they occur, you get one month with a heavy expenditure, or one year with a very heavy expenditure for reconstruction, and the next period with a low expenditure.

Depreciation is going on all the time, whether we recognize it in our books or not, and if we do not make it good by regular charges, we shall be obliged to make it good all at once when we have to. We have a battery of boilers, perhaps, which are depreciating all the time; we repair them constantly, but by and by we get to the point when they are beyond repair, and we have to throw out the whole battery and put in new. This — the throwing out of the whole battery — would be a proper charge against depreciation reserve. The repairs which we have made upon those boilers from year to year would be a proper charge for maintenance to be carried against income. This distinction is the one that I should like to impress upon you, if I can, as the result of our experience on these various lines. It would not be so emphatic if we had had to do only with water works, but, seeing how important it is in other classes of public corporations, there is no doubt in my mind that it will come to be equally as necessary and equally as required by state boards of control from water works, as it is now in the case of other public service corporations.

Mr. Elbert Wheeler.* Mr. President, I want to express my thorough approval of the remarks of Mr. Chase. I think they are perfectly sound, and the managers of our public service cor-

* Treasurer of Water Companies, Boston, Mass.

porations will not be justified in conducting their business without full attention to the details he has mentioned.

He spoke of the necessity of providing for renewals of integral parts of a plant through this depreciation reserve fund, by fixing rates which shall provide therefor. In the Knoxville Water Company case, in which our people are interested, and which, I presume, is familiar to many of you, Mr. Justice Moody, of the United States Supreme Court, said, in effect, this: That it is the duty of all public service corporations to fix rates which shall provide for depreciation, and that they are without excuse if they fail to do so; and, further, that they cannot be allowed, through having made insufficient rates in one period of time, to make rates in a future period calculated to make up the deficiency resulting in the previous period. That emphasizes the importance of providing for sufficient income to cover depreciation out of current rates, from time to time.

I wish simply to add that we have already entered upon the measures which Mr. Chase proposes, excepting, that we shall not make the accounting monthly, but periodically,— probably annually,— although we recognize the desirability, in the case of some corporations, of providing for such accounting more frequently than once a year.

Mr. Allen Hazen.* We all know, as a matter of practical experience, that it is necessary to mark off something for depreciation on a water-works property in order to keep it solvent.

As a matter of business it is just as necessary and just as important to know what the depreciation really is, and to mark it off, when the plant is owned by a municipality as it is when it is owned by a private company. This is a point that I want to emphasize strongly, for I believe in it fully. Water works that are owned by municipalities ought to be managed just as carefully, on good business self-supporting lines, as though they were owned by private corporations and had to earn dividends.

The annual amount that ought to be marked off for depreciation is a very troublesome matter to determine. It has been my idea that the best that could be done was to approximate that amount as closely as it could be done on the basis of available

* Civil Engineer, New York City.

information as to properties that have been long in use, in case of doubt making the allowance above the truth rather than below the truth, and mark it off each year. After a few years compare the book value of the property carried forward in this way with the actual value, as it can be appraised at the time, and see how they are coming out, and increase or decrease the allowance for depreciation according as your book value is underrunning or overrunning the true value.

This is a crude procedure, but at present it seems to be the best that can be done, and the fact that it is crude and that the amounts cannot be determined with precision should not be allowed to stand in the way of the recognition and application of a principle that we all recognize as essential to the best management of water-works properties.

Mr. George A. Kimball.* Mr. President, I have been very much interested in Mr. Chase's remarks on the importance of charging off a certain annual sum for depreciation. The system should be adopted by all cities and private companies. There is considerable difficulty in arriving at a proper ratio or percentage. For instance, take the question of the life of cast-iron pipe. Some engineers put its life at one hundred years, and I have seen a good many specimens which would seem to be good for that length of time; while other engineers place it at fifty years, and still others at only twenty-five years. Gates, valves, and hydrants are sometimes estimated at one half the life of the mains. In pumping plants the life of the boiler is estimated at from fifteen to twenty years, pumping machinery at a little longer time.

In regard to a proper sum to be charged off each year, I have frequently used 2 per cent. on the whole plant as a fair charge for depreciation, this to cover general deterioration, obsoletism, and renewals.

Mr. Charles W. Sherman.† I am glad that Mr. Hazen has emphasized the point that depreciation is just as much a matter of importance to a municipally owned plant as it is to a private plant. It is undoubtedly a fact that in a very large percentage, if not in all, of our municipally owned water works the accounts

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† Principal Assistant Engineer with Metcalf & Eddy, Boston.

which we see published in the reports, and presumably the only accounts kept, are those of receipts and expenditures, and in no sense a profit and loss account. Rates predicated on such accounts are, of course, matters of guess work, just as much as they are in any concern where depreciation is neglected, or where other items of expense are not brought in. The question of rates is a live one just at present in the town of Belmont. We have the matter under discussion there, and I hope we shall be able to work things out on a proper profit and loss basis with the data which have been obtained in past years. We ought, I think, to be able to estimate the value of the plant fairly closely, so that a proper ratio of depreciation for the term since the construction of the works can be fixed. That is not so easy in many other places, where other and more complex items come in. As most of you know, we, being in the metropolitan district, do not have to maintain a pumping plant, and the distribution plant only has to be considered. Nevertheless, the matter of functional depreciation, that is, the outgrowing of the plant, has to be considered, and it is still pretty largely a matter of guesswork as to how long a pipe can be made to last, not so much on account of rusting out as on account of having to be replaced by larger pipes. That suggests a point which Mr. Chase did not elaborate, which I should be glad if he would say a few words on, and that is that when it becomes necessary to renew a portion of a plant in any growing community, it is usually necessary to renew it with a larger and more expensive piece of apparatus; and in that case it would seem to me as if a part only of the renewal should be charged against the depreciation fund, and the balance should be charged to new construction.

Mr. Francis W. Dean.* It seems to me that there is a great deal of education needed on the part of cities and towns, and especially the smaller towns, in regard to matters of this kind. It would seem that it would be necessary, before a depreciation account was established, to teach the officials of the town something about a proper way to keep their accounts of anything. For instance, an appropriation is made by a town for the waterworks department, and the money is thrown into the treasury

* Mill Engineer and Architect, Boston.

and is used for the purchase of spraying apparatus for moths, or for the selectmen's salaries, or for anything else; there is no separate account whatever kept. Of course, it is only common sense that there should be a depreciation account, and I fully agree with Mr. Chase in everything he has advocated, but I must confess that the manner in which town accounts and finances are usually run passes the understanding of any sensible man.

Mr. Frank C. Kimball.* I thoroughly agree with the idea that has been expressed, that a depreciation reserve is as much a part of the operating expenses of any plant as are salaries, repairs, or maintenance; in fact, somewhat more so, perhaps, because through proper management other expenses can be to some extent diminished, but depreciation itself, although we do not know to what extent, is substantially fixed. I think there can be no question about that.

In that connection, I think, perhaps, the method of handling depreciation, as stated by Mr. Hazen, can be worked out in a way which will accord with the decision as rendered by Mr. Justice Moody by making the estimate for depreciation large enough at the start and then scale it down when you find by experience that it is too much. Mr. Justice Moody says you cannot make up arrears of depreciation, but he does not say that you cannot make it large enough at the start to be sure of reimbursing the works or the department.

I think there is no one here to-day who will have the temerity to state in terms of a specific sum or percentage the amount which should be laid aside yearly for depreciation upon any water-works plant, or upon any part of it. Those of us who have given more or less time to the study of this question know that the opinions — and it is at the present time purely a matter of opinion — of those who have investigated this question to as full an extent as it may at present be investigated, differ, and we can only let time and experience work out just what is the proper amount.

I believe that the question of depreciation is just as much, and as important, a question with water-works plants as it is with electric light or any other plants. The only difference is in the

* Civil Engineer, Boston, Mass.

amount. In water-works plants, the various component parts do not depreciate as fast as do those of certain other corporations, public service corporations particularly, but that depreciation does go on is without doubt. There are other features than the mere normal wearing out of water pipe in itself that enter into the problem. For instance, in Cambridge, I can readily understand how electrolysis may affect the life of pipe and in such a slow, insidious way that you cannot say definitely that electrolysis is the cause of the trouble, — that is, to a point where you can charge it up to the electric light or railway company. But still, comparatively rapid deterioration is going on, and this as well as other circumstances must be taken into consideration. That the establishment of a depreciation reserve is a necessary policy which should be followed by every water plant, whether municipally or privately owned, there is no question in my mind.

The question has been raised here this afternoon as to how a city, for instance, which establishes a depreciation fund or reserve can be prevented from spending it in other ways and methods than that for which it was created. You can do it in just exactly the same way that a sinking fund is taken care of; that is, by having an actual contribution made to such a fund, and then have it placed in charge of and invested by the sinking fund or other commission that may be appointed by law for that purpose, and providing that it be used only upon proper certificate of the controlling officers of the plant that it is required to make good such replacements or reconstruction of the plant as are properly chargeable against that fund. There is really no difficulty in the way, and I think the sooner all companies or departments come to the conclusion that the depreciation is as much a fixed charge as interest or other expense accounts, and proceed to provide for it, the better off they will be.

Mr. Leonard Metcalf.* Mr. President, I am exceedingly glad that Mr. Chase has brought this matter up, because it seems to me of great importance.

I think Mr. Kimball hit the nail on the head exactly when he said, "Make your depreciation large enough." That is in accord not only with good policy on the part of the private corporation,

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* Of Metcalf & Eddy, Boston.

but I believe it is sound public policy; for the public, certainly, cannot benefit either by seeing the plant actually divided by having funds disbursed as dividends which should have been retained for depreciation, nor can it benefit by having the rates so small that the plant cannot earn its depreciation account.

Mr. Kimball is quite right, too, in what he says concerning the amount of depreciation; it varies, of course, in different cases with local circumstances. I would, however, call your attention to the important fact in this connection: that unlike electric light plants or gas plants, the amount of depreciation in water-works property is small, and while it may differ in individual cases to the extent of from three quarters of 1 per cent. per annum to 1½ or even 2 per cent. on the cost of the plant, the effect of this difference in depreciation is very small when pro-rated upon the rates of the individual water-rate payers. Under these circumstances it is a far wiser policy to make liberal provision for depreciation and then at intervals reduce the amount charged off for depreciation if it is found to be excessive than to run the risk of failing to collect enough to cover the actual depreciation.

Just one word as to what effect this would have upon the rates. The essential difference, as I view it, between the electric light or gas company's position, referred to by Mr. Chase, and that of the water company, is that the percentage which the gross annual income on the water company's property constitutes of that entire property is very much less than in the case of the electric or gas company. The gross earnings on water-works properties vary, broadly speaking, from 10 to 15 per cent. per annum of the value of the works. That is, on a plant having a value of $100 000, the gross income may be from $10 000 or $12 000 to $15 000. In the case of the electric light property, on the other hand, the gross annual income is not 10 to 15 per cent., but from 30 to 40 per cent. But the depreciation in the case of water-works property is only, let us say, 1 per cent. or thereabouts, — it may be from 1 to 2 or more per cent. That would be, on a property of $100 000, a depreciation of $1 000 a year, and would amount to from one tenth to one fifteenth of the gross annual income. In the case of an electric plant, the depreciation might be 5 or more per cent. of the value of the plant, or $5 000 or more

on a $100 000 property. You have, therefore, in the one case to distribute a depreciation of $1 000 on $12 000 to $15 000, and in the other case you have to distribute $5 000 on $30 000 to $40 000, or from one sixth to one eighth of the value of the plant. On that basis, you see, small as it is, in per cent. of value of the works, the amount of the depreciation found in water-works property becomes nearly as considerable a percentage of their annual gross income as is the depreciation in the case of electric or gas property.

I want to make an appeal to you for such information as you can give me regarding the depreciation in your individual plants. I happen to be at the moment on a depreciation committee of the American Water Works Association, which is trying to gather statistics of this sort, taking the records, the histories, of such plants as we can get information from, and attempting to find out what has been the actual experience in those individual plants in depreciation, — that is, what mains have had to be abandoned and relaid, what pumps, piping systems, or reservoirs have had to be abandoned, in the hope of getting a little more specific information upon which we can base our estimates of the actual depreciation in water-works property,— and I should be very grateful to any of you who have any specific information along those lines, particularly those of you who have been connected with any one system of water works long enough to know the history of the works, if you could assist me in getting some such information.

Mr. Dean. I should like to ask if it would be practicable to have the findings of this committee, to which Mr. Metcalf refers, published in our own transactions, when the report is made? I don't know whether anything of that sort is allowable, but if it is not, it would seem as if it might be advisable to have a committee of our own, and if the personnel of that committee could be the same as that of which Mr. Metcalf speaks, it would make the labor a good deal less.

The President. That matter can be taken up by the Executive Committee at their next meeting, and we will see what we can do.

Mr. Samuel H. McKenzie.* Mr. President, I think the

* Superintendent of Water Works, Southington, Conn.

remarks of Mr. Dean appeal to a great many of us who come from the small places. I am from one of these small towns which I presume he had in mind, but I am glad to report that our present town clerk has opened a set of books which are a credit to our town. I think those of us who are connected with water departments are realizing more and more each day that our accounts should be kept in a more systematic way.

The passing of the Corporation Tax Bill by Congress has made it necessary to establish a depreciation account, which is something, as Mr. Chase has already said, that few water departments, especially the smaller ones, have been in the habit of keeping. Some might like to estimate the depreciation large enough to get their net income under the $5 000 limit, but I doubt if the Internal Revenue collector would consent to that.

There are very few manufactories who have not figured the cost of the articles they make, but how many water departments know the cost of the water they furnish, or the proportional charge which should be made for different classes of fixtures. Often, it seems as if the rates were guessed at without any idea of the cost of delivering the water, or the depreciation of the plant. There are very few systems in which the cost per million gallons of water furnished is identical on account of the varied conditions under which they have been built, but, nevertheless, I believe with a more systematic accounting that data could be obtained which would be of great value.

If the Association can assist in helping to establish a uniform system of accounting so that the percentage of depreciation of different parts of the plant may be determined and more equitable rates made, it will be performing a service which will be appreciated by the members, and I believe a committee should be appointed to take the matter under consideration.

Mr. Edwin C. Brooks.* I was thinking, Mr. President, as the gentlemen have been speaking of depreciation, that if you could have seen some of our 40-inch steel pipe when we uncovered it eight years ago, you would have thought that about 100 per cent. should be charged for depreciation. However, with a few pine plugs and some cover-plates bolted on with rubber gaskets

* Superintendent of Water Works, Cambridge, Mass.

under them, we managed to repair the pipe while it was in use, and since that time haven't heard a word from it in any way, shape, or manner. Of course, we are not taking it up to find out whether there is anything the matter with it, for we are satisfied to "Let sleeping dogs lie."

But, really, on the question of depreciation, we have mains that have been in use fifty years which are doing just as good service to-day as they did forty years ago. We cut into them occasionally and find them perfectly good. We have got other sections where Mr. G. A. Kimball has got in his work, and those pipes need to be renewed about every year or every two years. Of course, that is one of the things we didn't have to contend with years ago.

I realize fully that depreciation is a matter of vital importance in water-works management, and I think the water-works plant that is the oldest will suffer most in depreciation, for this reason: Years ago there wasn't that thought given to the sizes of distribution mains that there has been in recent years. Long lines of small pipe were laid without any idea of reinforcing them, fire service was not what it should be, and, consequently, certainly in our own case, a great deal of main pipe has been renewed which, had it been put in of the proper size in the first place, would have probably continued in use for a great many years to come. Our steel mains were put in with a great deal of fear on the part of some that they were going to give us trouble, but, as I say, other than for that little trouble we had about eight years ago, we have had no trouble whatever from them.

Mr. George A. Stacy.* Mr. President, we all must recognize that this is a vital question. I have been with my present works twenty-six years and, so far as the pipe line goes, whenever I have had to cut into a pipe I could detect very little deterioration. Last summer we cut into a 12-inch main which was laid in 1883, and, although it had been there twenty-six years, I couldn't see but that it was good for twenty-six years more. Our works, like many others, were built by a committee of business men who figured pretty close, and, having had no previous experience, they laid some 4-inch pipe in a district which never ought to

* Superintendent of Water Works, Marlboro, Mass.

have been piped that way. In fact, the only disagreement or discord I ever had during my connection with these works was when I questioned the advisability of laying 4-inch pipe. I took some of that pipe up about four years ago and put in a larger pipe. Those men were some of our best business men, but they had not had experience with water works; they looked at the first cost, and a 4-inch pipe would deliver all the water that that district needed then, for it was thinly populated and rather on the outskirts. We had a fire in a barn out there, and the firemen couldn't get near enough to it to get the water on to the barn with the force they had from that line. Fortunately, from one point of view, the barn was a wreck before the fire was discovered, so that the lack of water didn't cut much, if any, figure in the loss of property, but I didn't have any trouble in getting that 4-inch line renewed immediately.

That brings to mind that this is a question, perhaps, of the deterioration of a plant, and there are many things that occur to you as you look back on your experience that go into this question to which you cannot see the answer. However, I believe that there is something we can arrive at which will help us out of this.

For instance, take the boiler plant. I have got one plant pumping against 180-pounds pressure, over 408 feet head, and it calls for 120-pounds steam pressure. Those boilers may be condemned by the State Board of Inspection and cut down to 115 pounds. The result is that those boilers have got to go out; we can't run on 115 pounds economically. What are we going to do with them? It is a question what the boilers would sell for. After you get them out on the ground, those who have been through that thing know about what they are worth. All those matters and hundreds of others come into your mind in solving this problem. I have got an old Blake pump that has been running almost every day all these years. It is one of those old tandems, compound and duplex, and as I overhaul the steam cylinders I don't see but what it is good for fifty years more. So this question of depreciation seems to me would have to be taken up, to a certain extent, according to local conditions.

From my experience, so far as the length of life of pipe is concerned, I don't see any reason why the pipe in Marlboro should

not last for seventy-five years. I am surprised that any statement should be made that pipe wouldn't last over twenty-five years, for I guess the old cement pipe does better than that. I think fifty years under average conditions would be very low for the life of cast-iron pipe. Of course, the tubercles forming inside cut down your supply some, but so far as the pipe goes, I think good cast-iron pipe under average conditions is good for seventy-five years at least.

Mr. R. C. P. Coggeshall.* Mr. President, perhaps it is digressing a little from this discussion, but I should like to refer a moment to the practice among city councils of applying water-works funds to other purposes. Mr. Chase has had a good deal to do with our accounts in New Bedford, and he is very familiar with them. Our pumping station lot, for instance, which was wholly paid for out of the original water bonds, has been taken almost entirely away by the city council and is now used by other departments of the city, without any credit being given to the water department. The railroad company in raising the grade of their tracks took possession of a part of one of our reservoir lots. The proper award was made, but the city council took good care that it was carried to other accounts. That sort of thing is constantly occurring in connection with water-works matters. In the city of Fall River, for years they took a large slice of the income of the water works and devoted it to other purposes; and in many places the municipality does not contribute one cent to the water department for the water that is used. That was changed in our city two years ago. Now, in order to get at the thing exactly, and I believe in a depreciation charge, it seems to me that the city council itself has got to be educated up to giving proper credits to the water department.

Mr. Samuel H. McKenzie. Mr. President, I should like to inquire if any members present have had experience in cleaning mains.

If they can be successfully cleaned at a reasonable cost, the life of the pipes will be lengthened and the per cent. of depreciation materially lessened.

Mr. Edwin C. Brooks. We had about 1 800 feet of 6-inch

* Superintendent Water Works, New Bedford, Mass.

pipe cleaned which had been laid for twenty odd years, and with very gratifying results. It was a small matter, and as there happened to be just a little money available for that purpose, we spent it in cleaning the pipe rather than in digging up the street to lay a new main. The cost of this cleaning was about $290.

Mr. Harvey S. Chase. The question of town accounting as a whole has been referred to. Director Gettemy, of the Statistics Department, under the statutes passed in 1906, now has practical mandatory control over the accounting of cities, although he has not utilized that power as yet; that is, he is working along the lines of least resistance and is suggesting and advising and gradually bringing the towns and cities up to a proper realization of the importance of the matter. I think he is doing it in exactly the right way; but he has mandatory power so that he can compel a city or town at the present time, if he desires, to keep its accounts according to the requirements of the commonwealth. Along that line the developments are going to come, not only for the ordinary accounting of towns, but for the water works of towns and cities, and by a standardization at the center of things here in the Bureau of Statistics a development of accurate and uniform methods will be found for water works, including that question of depreciation. Of that I have no doubt. It will take time, of course, but it is being worked out not only in Massachusetts, but in other states, in Ohio particularly, and in Indiana and in Kentucky, and in various other states.

As to the question of reconstruction, that is to say, when a 4-inch main is to be taken up because it is not large enough, and a 6-inch or an 8-inch is to be laid in the place of it, it is asked how we should handle that in our accounts. We have laid aside monthly, we will say, an amount in the depreciation reserve for mains, which has been growing month by month and year by year, until we have an amount of $25 000, or whatever it may be, reserved. That applies only to mains; that is the depreciation reserve for mains. Aside from that account, we have a depreciation reserve for pumping plant, another depreciation reserve for services; and, in fact, we need just as many depreciation reserves as we have classes of assets, because the percentage of depreciation on each one of those classes of assets is different, as is familiar to all of us,

and as has been stated here. Now, taking the one case, here we have a reserve for mains. On our books in our plant accounts, we have the total cost (which may be subdivided if we desire) of our mains as they now lie in the streets. Now we are going to pull up a portion of that 4-inch pipe, 2 000 feet, or whatever it may be, and replace it by a 6 or 8-inch, and how shall we handle this in our accounts? We know by keeping records what the cost of laying the new pipe is. We charge that immediately to our plant account (on the left), increasing our plant account by so much. We now subtract from the plant account the original cost of the 4-inch main, by crediting the original cost to the plant account, and charge the same amount against the depreciation reserve for mains. In this way we take care of everything, you see, and very simply. We have got a record then of the actual cost of the new pipe which has gone in, and we have also taken out the cost of the old pipe and have charged it up into depreciation reserve, where it belongs.

The balance of these depreciation reserves should, of course, be carried forward from year to year, and should not be closed up at the end of the year. Thus we go on with new credits and new charges from year to year. If we find we are accumulating too much in any one of these depreciation reserves, that is, if we find (after taking obsolescence into account) that the credits are running too big, naturally we will cut down our rates for depreciation per month, but we do it only when we are convinced that the reserve is too big. On the other hand, if it is too small, and our actual expenditures are greater than the amount of our reserve, we will, of course, increase the percentages. I imagine that any decision by Mr. Justice Moody would not interfere with that, if it is properly done, and done frequently enough. I imagine there would not be any trouble with the courts about doing that.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 9, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, J. M. Anderson, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, F. D. Berry, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, G. A. P. Bucknam, James Burnie, W. L. Butcher, R. D. Chase, H. W. Clark, R. C. P. Coggeshall, M. F. Collins, J. W. Crawford, A. W. Cuddeback, G. W. Cutting, Jr., E. R. Dyer, F. B. Forbes, F. L. Fuller, F. J. Gifford, T. C. Gleason, A. S. Glover, J. A. Gould, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, T. G. Hazard, Jr., M. F. Hicks, H. G. Holden, J. L. Howard, F. M. Hutchinson, E. W. Kent, Willard Kent, Patrick Kieran, F. C. Kimball, G. A. King, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Merrill, G. F. Merrill, H. A. Miller, William Naylor, G. A. Nelson, F. L. Northrop, E. M. Peck, T. A. Peirce, J. L. Rice, Henry Roberts, Ransom Rowe, P. R. Sanders, A. L. Sawyer, S. P. Senior, E. M. Shedd, C. W. Sherman, H. O. Smith, W. E. Smith, G. H. Snell, J. T. Stevens, E. L. Stone, W. F. Sullivan, C. N. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, C. H. Tuttle, W. H. Vaughn, C. K. Walker, R. S. Weston, G. E. Winslow. — 78.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Ashton Valve Company, by C. W. Houghton; Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by H. L. DeWolf; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; F. H. Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by Arthur R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by W. G. Ryan and H. W. Hosford; Pittsburg Meter Company, by F. L. Northrop; Rensselaer

Manufacturing Company, by Charles L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by W. F. Hogan. — 23.

Guests.

Albert S. Benson, chemist, East Greenwich, R. I.; Charles R. Hildred, Somerville, Mass.; Harry L. Whitney, W. H. Larcom, Beverly, Mass.; E. B. Curney, W. H. Putnam, Lowell, Mass.; George H. Stevens, Dracut, Mass., and D. H. Hall, Bridgeport, Conn. — 8.

The Secretary read the application of Harry L. Whitney, city engineer of Beverly, Mass., for membership in the Association, properly endorsed and recommended by the Executive Committee. On motion of Mr. Peirce, the Secretary was directed to cast one ballot in favor of the applicant, and he having done so, Mr. Whitney was declared elected a member of the Association.

The President then called for any practical questions for discussion.

To the following question, submitted by Mr. Rowe, "Is it practicable or necessary to clean water mains in New England? Can water mains be cleaned by machine?" there were no answers.

A question in regard to the vibrations or water hammer in pumps was discussed by G. F. Merrill, S. A. Agnew, C. N. Taylor, F. L. Fuller, H. L. Thomas, F. H. Hayes, A. E. Martin, and R. C. P. Coggeshall.

Mr. Desmond FitzGerald, civil engineer, of Boston, then addressed the meeting upon the subject, "Medieval Times of Germany," illustrating his remarks with stereopticon slides.

Mr. H. W. Clark, chemist of the Massachusetts State Board of Health, Boston, then read a paper entitled, "Double Filtration of Polluted Waters."

The President. There is a question in my mind whether the members understand that headquarters are open every day to members of this Association. It might appear from our notice that the room is open only the day of the meeting, but that room is open to you all the time, every day, and you are at liberty to use it as you wish all through the week.

Adjourned.

April Meeting.

Allyn House,
Hartford, Conn., April 13, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, E. W. Bemis, F. D. Berry, J. F. Bigelow, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, L. G. Carleton, C. F. Chandler, J. H. Child, M. F. Collins, H. R. Cooper, G. K. Crandall, E. D. Eldredge, E. A. Fisher, J. A. Fitch, E. V. French, T. C. Gleason, R. A. Hale, R. K. Hale, F. E. Hall, J. C. Hammond, Jr., A. E. Hansen, W. H. Hart, A. R. Hathaway, Allen Hazen, A. B. Hill, W. E. Johnson, Willard Kent, G. A. King, F. C. Kemble, J. J. Kirkpatrick, H. O. Lacount, B. C. Little, E. E. Lochridge, Daniel MacDonald, S. H. McKenzie, T. H. McKenzie, A. E. Martin, W. E. Maybury, J. A. Newlands, F. L. Northrop, O. E. Parks, E. M. Peck, W. H. Richards, Henry Roberts, H. W. Sanderson, A. L. Sessions, E. M. Shedd, C. W. Sherman, G. A. Stacy, W. F. Sullivan, J. L. Tighe, J. A. Tilden, J. H. Walsh, H. L. Whitney, I. S. Wood. — 60.

Associates.

Anderson Coupling Company, by C. E. Pratt and G. W. Hayden; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Robert Shirley; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; Gamon Meter Company, by C. A. Vaughan; Glauber Brass Manufacturing Company, by S. S. Freeman; Hersey Manufacturing Company; by J. A. Tilden; International Steam Pump Company, by Samuel Harrison, Lead-Lined Iron Pipe Company, by T. W. Dwyer; Charles Miller & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by A. C. Pilcher; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by T. D. Faulks; Pittsburg Meter Company, by F. N. Northrop; Rensselaer Manufacturing Company, by C. L. Brown and F. S. Bates; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; R. D. Wood & Co., by W. F. Woodburn. — 22.

Guests.

H. L. Haines, water commissioner, Springfield, Mass.; William C. Pollett, A. E. Lavery, and D. H. Hall, assistant superintendent, Bridgeport, Conn.; William R. Edwards, Paterson, N. J.; G. M. Clukas, Cambridge, Mass.; A. W. Jepson, Bristol, Conn.; Charles L. McNeil and Isaac W. Brooks, Torrington, Conn.; William S. Scranton, superintendent, Durham, Conn.; T. A. Collins, Philadelphia, Penn.; Nelson D. Merwin, Ezra Cutting, A. C. Hall, Mr. Greenwood, L. W. Goodrich, H. L. Phillips, Hon. E. L. Smith, F. S. Cary, Ferdinand

Richton, F. C. Sumner, John L. Down, Shiran Morris, James F. Shaughnessey, Hartford, Conn.; Ernest Farrell, Holyoke, Mass.; Robert K. Tomlin, Jr., *Engineering Record*, New York City; Anthony Adams, superintendent, Stafford Springs, Conn.; J. P. Steele, C. A. Cook, Marlboro, Mass.; James J. Walsh, Meriden, Conn.; E. B. Bronson, Winsted, Conn.; E. L. Burnap and A. S. Comstock, Norwich, Conn. — 33.

The President called the members to order and presented his Honor Mayor Smith, of Hartford, who spoke as follows:

MAYOR SMITH. *Mr. President and Gentlemen of the New England Water Works Association,* — It is extremely pleasant for me to be here to welcome you to Hartford in the name of the city. It may not look so, but it is a fact, that I have been connected with the water works of the city of Hartford for about seven years. I was associated with this body of gentlemen on my right, who represent the Water Department here at this meeting, and for seven years I helped them, doing what I could to provide the city with a pure water supply. It was one of the vicissitudes of human experience that last year I retired from the Water Board and went back to the silken ease of my library in the classic shades of the Trinity campus, and took up the study of Epictetus and Allen Hazen on filtered water supplies, to calm my disturbed spirit.

The city of Hartford is very much interested at the present moment in the water question. If you gentlemen are to discuss that question you will have a very interested audience throughout the city. If you are going to discuss the forestry question, as I understand from your President you may, you will have an equally interested audience, for some of us are not yet out of the woods. This is the very first convention that I have addressed as mayor of this city, and no convention would I prefer to address rather than one that is interested in the work that I have been interested in. I trust that your visit here will be as pleasant as the most enthusiastic of you could desire. We are proud to have you here, and so far as in our power lies we will try to make you thoroughly welcome.

The President, after thanking the mayor for his presence and for his words of welcome, announced that it had seemed desirable to change the date of the September meeting at Rochester from September 14–16 to September 21–23, just one week later. He

then called upon the Secretary to present the applications for membership.

The Secretary read the following list of applicants:

Active. — J. Walter Ackerman, superintendent of the Municipal City Works, Auburn, N. Y.; Raymond W. Ferris, Columbus, Ohio, sanitary engineer, has been engaged in the engineering departments of the State Boards of Health of Massachusetts and Ohio; Herman K. Higgins, Boston, has been engaged in sundry water supply projects, including design of dams, channels, and filters at Gatun, Canal Zone; William H. Wilson, Burlington, Vt., superintendent of Burlington Filtration Plant; Cyrus C. Babb, Augusta, Me., district engineer, United States Geological Survey; R. J. Sandford Sly, Toronto, Ont., civil engineer; James J. Walsh, Meriden, Conn., superintendent of the Meriden Water Works; Leonard H. Davis, Sault Ste. Marie, Ont., chief engineer, Lake Superior Power Company, the Michigan-Lake Superior Power Company, the Tagona Water and Light Company; Edwin L. Burnap, Norwich, Conn., superintendent water works; George A. Carpenter, Pawtucket, R. I., city engineer; John K. Barker, Springfield, Mass., engaged in general engineering, mill, and hydraulic work; Albert S. Comstock, Norwich, Conn., water commissioner; Isaac W. Brooks, Torrington, Conn., president of water company. — 13.

Associate. — George M. Clukas, Cambridge, Mass., with the Pennsylvania Cement Company; American Asphaltum and Rubber Company, Chicago, Ill., manufacturers of "Pioneer" mineral rubber pipe coating and "Pioneer" reservoir waterproofing asphalt; Fred A. Houdlette & Son, Inc., Boston, cast-iron pipe and structural materials (reinstated). — 3.

On motion of Mr. Brooks, of Cambridge, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so, they were declared elected.

Under the head of "Topical Discussion," which was next on the program, the question, "Is it practical or necessary to clean water mains in New England? Can water mains be cleaned by machine?" was considered by Mr. E. C. Brooks, Mr. F. A. McInnes (by letter), Mr. McKenzie, Mr. Kemble, Mr. Robert Shirley, Mr. Allen Hazen, and Prof. Edward W. Bemis. Then Mr. George A. Stacy brought up the subject of the comparative advantages of a round multiple and a straight reading register for a water meter. Mr. J. A. Tilden, Mr. J. C. Hammond, Jr., Mr. C. W.

Sherman, and the President also spoke on the subject. Mr. Kemble asked for information as to the difference in the effect of an alternating current and a direct current in producing electrolysis, but no one replied to his question.

Mr. E. E. Lochridge opened the discussion on "Secondary Water Supplies, Their Dangers and Value." He was followed by Mr. William F. Sullivan, Mr. E. C. Brooks, Mr. John J. Kirkpatrick, Ermon M. Peck, Robert Shirley, George A. Stacy, Edward V. French, M. F. Collins, Prof. Edward W. Bemis, and J. H. Child.

Mr. L. W. Goodrich, Forester for the Water Department of Hartford, read a paper on "Forestry." The subject was discussed by Professor Hawley, Mr. E. B. Bronson, and Mr. William F. Sullivan.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, March 9, 1910.

Present: President George A. King and members Frank A. McInnes, Lewis M. Bancroft, George W. Batchelder, Robert J. Thomas, Richard K. Hale, Ermon M. Peck, Michael F. Collins, and Willard Kent.

Voted: That the Committee on Annual Convention be invited to send a representative to attend the April meeting of the Association at Hartford, Conn., at the expense of the Association.

Voted: That Mr. William F. Woodburn be and hereby is appointed a Committee on Exhibits at the next Annual Convention with authority to appoint an assistant.

Voted: That the program of the April meeting contain notice that applications for membership will be received and acted upon at that time; also of any other business that may appear necessary prior to issuance of program.

Voted: That the Secretary be and hereby is authorized to make arrangements for hotel accommodations for the next winter's meetings of the Association.

Voted: That Messrs. George W. Batchelder and Robert J. Thomas be and hereby are constituted a Committee on Transportation for the next Annual Convention.

The President, Committee on "Boston 1915," reports that he has performed his duties, and upon his recommendation it was

Voted: That Mr. Frank A. McInnes be and hereby is made a committee to represent the Association at the future meetings of "Boston 1915."

Adjourned.

WILLARD KENT, *Secretary.*

Boston, Mass., March 24, 1910.

Meeting of the Executive Committee at headquarters, 715 Tremont Temple, at 2 o'clock p.m., at the call of the President.

Present: President George A. King and members Robert J. Thomas, Lewis M. Bancroft, Frank A. McInnes, Ermon M. Peck, Michael F. Collins, Richard K. Hale, and Willard Kent.

A letter was read from Albert H. Wehr, chairman of Committee of American Water Works Association on Uniform Water Works Accounts and Reports, inviting the Association to send a representative to attend a conference with the Hon. LeGrand Powers, chief statistician of the Bureau of the Census, and others.

It was voted that the invitation be accepted and President King was appointed a committee to attend said conference, his expenses to be borne by the Association.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee, April 13, 1910, at Hotel Allyn, Hartford, Conn.

Present: President George A. King and members Edwin C. Brooks, George A. Stacy, Michael F. Collins, Irving S. Wood, Ermon M. Peck, Richard K. Hale, and Willard Kent.

Thirteen applications for active membership were received, as follows: James J. Walsh, superintendent water works, Meriden, Conn.; Edwin L. Burnap, superintendent water department, Norwich, Conn.; Isaac W. Brooks, president water company, Torrington, Conn.; John K. Barker, civil engineer, Springfield, Mass.; R. J. Sanford Sly, civil engineer, Toronto, Ont.; Herman K. Higgins, consulting engineer, Boston, Mass.; Cyrus C. Babb, district engineer state water storage commission, Augusta, Me.; William H. Wilson, superintendent filtration plant, Burlington, Vt.; Leonard H. Davis, chief engineer, The Lake Superior Power Company, Sault Ste. Marie, Ont.; J. Walter Ackerman, superintendent municipal water works, Auburn, N. Y.; Albert S. Comstock, water commissioner, Norwich, Conn.; George A. Carpenter, city engineer, Pawtucket, R. I.; and Raymond W. Ferris, assistant engineer, Ohio State Board of Health, Columbus, Ohio.

Two applications for associate membership were received as follows: Pennsylvania Cement Company, Boston, Mass., and The American Asphaltum and Rubber Company, Chicago, Ill.

One application for reinstatement to associate membership was received, as follows: Fred A. Houdlette & Son, Inc., Boston.

Voted: That it be recommended to the Association that the above-named applications be granted.

On motion of Mr. Stacy it was voted: That in order to better facilitate the arrangements for accommodations, the date of the Annual Convention of this Association for the present year, to be held at Rochester, N. Y., be and hereby is changed from that previously fixed to September 21, 22, and 23.

Voted: That fifteen dollars ($15) be and hereby is appropriated for expenses of Joint Committee on Society House.

Voted: That it is the opinion of the Executive Committee that the New England Water Works Association should lease quarters in the proposed Society House at an expense not exceeding five hundred dollars ($500) per annum.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

Dennis H. Gilderson.

Died March 14, 1910.

Mr. Gilderson, the son of Mr. and Mrs. William Gilderson, was born in Parsboro, N. S., in 1860. After leaving the public schools, he became a constructor for the C. L. Goodhue and Burnie Company, of Springfield, with whom he was associated for many years. In 1890 Mr. Gilderson built the water works at Bradford, and, on their completion, became superintendent. He held this position until the town was annexed to Haverhill, when he entered the office of the superintendent of that town. He became superintendent of the Haverhill Water Works in 1897, which position he held until his death.

Mr. Gilderson was married in 1886 to Miss Mary Furey, of Thompsonville, Conn., who with two sons survives him.

Mr. Gilderson was a charter member of the Bradford Lodge, A. O. U. W., a member of the Haverhill Lodge of Elks, of the Palestine Lodge of K. of P., and of the Holy Name Society.

Mr. Gilderson was elected a member of the New England Water Works Association on September 11, 1895.

BOOK REVIEWS.

Text-Book on Hydraulics. By George E. Russell, Assistant Professor of Civil Engineering, Massachusetts Institute of Technology. 6 x 9½ inches, vii + 183 pages. 124 illustrations in the text. New York: Henry Holt & Co. Cloth, $2.50.

As the author states in the preface, this book is intended for a text-book for a short course in hydraulics, where time will not permit of an extended study of the whole subject.

If it is acknowledged that a text-book for such a course should be a discussion of the fundamental principles only, leaving the applications to be supplied by the instructor, rather than a more or less complete reference book for use after the services of the instructor are no longer available, this work will be found most useful.

The subjects treated include definitions and units of measure, a discussion of the fundamental formulæ of hydrostatics, motion of liquids, discharge through orifices, weirs, tubes, pipes, and channels, and a short chapter on the dynamic action of jets, the pressure in pipe bends, and water hammer. The appendix contains the usual tables of weights, velocity heads, and coefficients.

The author omits turbines, pumps, and other hydraulic machinery, as well as the measurement of the flow of rivers.

The discussions are logically presented and well written. There are numerous lists of references to the more important of the subjects, and many problems to illustrate the principles considered.

The book is an exceedingly good presentation of the fundamental theories of hydraulics, but it would not be as useful for a reference book as a more extended treatise on the subject.

The Flow of Water: A New Theory of the Motion of Water under Pressure and in Open Conduits and its Practical Application. By Louis Schmeer, Civil and Irrigating Engineer. 6 x 9¼ inches, vii + 228 pages. Text illustrations and tables. New York: D. Van Nostrand Company. Cloth, $3.00 net.

The author states in the preface that the book is the outcome of a series of investigations to find a simple expression for the phenomenon of the flow of water in irrigating channels.

The author first discusses the variation of the velocity with the mean hydraulic radius, and the variation of the coefficient in the Chazy formula with the roughness of the wetted perimeter and with the velocity. With the aid of observed data from various sources, he then combines these relations into an exponential equation. By varying the exponent of this equation, and a

coefficient of roughness, this equation is said to fit all conditions of flow in pipes, conduits, or open channels. The complications involved may, perhaps, be judged by such expressions as "find the square root of the quotient and multiply by the seventeenth root of the square root," and the use of such exponents as the nine-forty-thirds, eighteen-seventeenths, and others. In spite of tables giving many values of these exponents, the solution of the equation under practical conditions is none too simple. There is, moreover, considerable doubt whether there are enough data on the flow of water in open channels to warrant the use of such an equation.

The author then discusses the general relations between the velocity discharge and depth of water in the form of section most favorable to flow, giving many tables of roots and powers. A short chapter on weirs follows, containing little new material. The appendix contains a discussion of the variation of the coefficient C with the slope, the author's formula expressed in metric measure, and a discussion of the most economical diameter of pipe.

As a whole, the method has little to commend it for practical work.

The Water Supply, Sewerage, and Plumbing of Modern City Buildings. By Wm. Paul Gerhard, Civil Engineer. 8 vo., xxxii + 491 pages, with 214 text illustrations, 15 tables, and 25 diagrams. New York: John Wiley & Sons. Cloth, $4.00 net.

As the author states in the preface, this book is the outgrowth of various lectures, revised and enlarged, with the addition of many tables, diagrams, and illustrations. The chapters are so written that each one is complete in itself, although this method involves numerous repetitions.

The book is well illustrated with photographs and drawings and cuts from manufacturers' catalogues, and its value is greatly increased by numerous, tables and diagrams of capacities and discharge of tanks, drains, service pipes, etc. Some of these diagrams could have been arranged a little more conveniently, and in some of them the coefficients used are not clearly stated. For example, in the table of discharge of orifices, nothing is said as to what coefficient should be used. It would be inferred from the table heading that the discharges could be used as given, whereas the values are the theoretical ones and are, therefore, almost twice as great as those commonly found in practical work.

The first two chapters deal with the essential features of the hydraulic and sanitary engineering of buildings, and contain a very complete description, fully illustrated, of the many sanitary fixtures and appliances in common use.

In the third chapter the author describes the plumbing systems that were formerly used, and the ones generally prescribed at the present time by building regulations and health boards. He then outlines an advanced system, which he has used in his own work, whenever unhampered by the regulations, which he considers much superior to the other systems because of its greater simplicity.

Chapter IV deals with plumbing in its relation to disease, and to the municipal control of plumbing. In this chapter the author points out that even if, as the best sanitarians claim, sewer air *per se* does not directly cause specific disease, it probably has considerable effect on the general health, and, therefore, it is essential to have plumbing correctly arranged. He also takes up the question as to which is the proper city department to inspect the installation of plumbing, and discusses some of the rules and regulations.

Chapters V and VI give a very complete treatment of the methods of supplying water to houses and city buildings, and contain numerous hydraulic tables and diagrams.

In Chapter VII the author discusses the maintenance of pipe system for sewage, gas, and water; with the methods of cleaning and flushing, the care of valves, faucets, and hydrants, and the protection of pipes against freezing.

Chapter VIII deals with plumbing rules, drawings, plans, and specifications and the quality of materials employed in plumbing, drainage, sewerage, and water supply. It seems to be largely a summary of preceding chapters.

In the appendix the author gives a very complete list of definitions of terms commonly used in sanitary engineering, an interesting historical sketch of the development of the art of plumbing, and a specification reminder, which will be found to be of considerable value in preparing specifications.

The book is unquestionably of considerable value to the architect, builder, and sanitary engineer, and will prove most interesting reading to any one interested in the subject, as well as to town officials who have to prepare or enforce plumbing regulations. Complete as the book is, it seems a pity that some mention of costs, and more data on the quantities of water and the number of fixtures to be provided, could not have been included.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

FORESTRY.

BY L. W. GOODRICH, FORESTER OF HARTFORD WATER DEPARTMENT.

[*Read April 13, 1910.*]

In considering the relation of forestry to water works, it may be well to begin by reviewing the condition of the forests in this part of New England, and the treatment recommended by foresters.

As is well known, the woodland of southern New England is nearly all second growth of sprout origin, most of the original timber having been cut off during the colonial period. As a rule, our forests are cut when forty or fifty years old and supply only material of small dimensions, principally ties, poles, piles, cord-wood,. and inferior lumber. Although American trees reproduce well by sprouts, the sprouting power of stumps falls off considerably after the trees reach the age of thirty or forty years. For this reason, in Europe sprout growth is cut at that age.

Trees of sprout origin are not as long-lived as seedling trees, consequently they do not reach the height and diameter growth of those from seed and produce a smaller and cheaper grade of lumber. When fifty years old they usually begin to rot at the butt, being infected from the old decaying stump. As virgin timber becomes exhausted in the states which now supply New England with the better grades of lumber, it will be necessary to produce this lumber locally. In order to obtain a higher grade of lumber from our forests, it is necessary in the first place to replace sprout growth as far as possible with seedling trees. One of the best methods which

can be used to accomplish this result is by what are called reproduction thinnings. A heavy thinning is made, taking out 30 to 50 per cent. of the stand. In doing this, defective trees and those of inferior species are removed. This opens up the stand and lets in light sufficient to promote reproduction of the most valuable trees by seedlings. As soon as satisfactory reproduction is assured, the remaining trees are taken out in one or two successive thinnings. Of course, there will be sprouts in the new stand, but there should be a considerable proportion of seedling trees.

Practically all of the woodland of southern New England is of one main type, that is, mixed hardwoods. The character of this type varies according to the quality of the soil on which it grows. On the deep rich soil of lower levels, chestnut, white and black oaks, and hickory predominate, while on the shallow soil of stony ridges, chestnut oak constitutes the bulk of the stand. Usually on poor soil the stand is not dense, and since trees like chestnut oak are useful only as firewood, it does not pay to make any thinnings. On the other hand, the trees on better soils are in a crowded condition and after the stand has reached its main height growth, improvement thinnings are made in order to increase the diameter growth of the most valuable species. When making these thinnings, dead, dying, and suppressed trees are usually all taken out and also those individuals which are interfering with the growth of the most desirable trees. By removing these trees, more light and growing space is given to the crowns of those which remain and the increased growth may shorten the time of maturity from ten to twenty years. The percentage of straight trees for ties and poles will be greater than without this treatment.

The area covered by forests in New England is steadily increasing on account of the many abandoned farms. Usually gray birch and red cedar are the first trees to take possession of these farms. If there are seed trees nearby, white pine seedlings establish themselves under the birches and usually in from ten to fifteen years the pines kill the birches because the latter are very intolerant of shade. In from thirty-five to forty years after it is abandoned, this land will produce from 12 to 15 cords of wood of small value. If, instead of waiting for natural reproduction to take place, these old fields are planted to chestnut or oaks, they would in from

thirty-five to forty years produce from 35 to 40 cords of wood, much of which could be cut for ties. It is probable that 100 piles would be produced on an acre besides about 50 ties and 10 cords of wood. At the present market price for these products this would be a return of over 3.5 per cent. on the investment.

Unless some method of purification of water is in use, water companies usually adopt the policy of acquiring by purchase absolute control of their drainage areas in order to keep off undesirable inhabitants. In carrying out this policy, the Hartford Water Department has purchased 3 300 acres of land, or about one half of the total watershed of the reservoirs. More than 50 per cent. of this area is sprout growth from five to fifty years old and is growing principally firewood. One third of the property is open land, including old fields which are growing up to birches, cedars, and other scattering trees.

In 1902 Prof. Henry S. Graves made a forest map of the tract and a plan for its management. The map shows in color the age of the compartments and in the plan a treatment is recommended for each portion according to its character, age, and condition. The carrying out of this plan will put the woodland in better condition and will also utilize the open land by planting it up as rapidly as practicable. Growing cordwood is profitable only when near a market, in fact, it should be only a by-product in good forest management. Our plan is to grow trees large enough for poles and lumber. Nearly all the thinnings thus far have been made in stands forty to fifty years old in which heavy cutting was done in order to procure some reproduction by seedlings. One thousand and sixty-two cords of firewood have been taken out in thinnings on 92 acres. Some of the wood was sold at a profit of 60 to 85 cents per cord over the cost of cutting.

The Hartford Water Department owns a lot of land which is being held solely for the protection of the supply from pollution. A large part of this land can be used in no way except for growing trees. This applies to the open land, some of which has a scattered growth of poor trees. Since 1903, 175 acres of this land has been planted up, using 125 000 white pine, 76 000 white ash, 20 000 hard maple, and other seedlings. In addition to this, we have planted directly, seed of chestnut, white and red oaks, and hickories.

In most cases the planting has been to pine in mixture with the other species; the permanent plantation is to be of nearly pure pine. One reason for planting in mixture is that it is cheaper; furthermore, pine grows clearer with a few hardwoods to help prune its lower branches. All but the choicest of the hardwoods will be taken out in thinnings. The indications are that the pine will outgrow most of the trees in the mixture except possibly white ash and red oak.

In preparation for planting, furrows are plowed 5 feet apart and the trees are then planted 6 feet apart in the rows, or about 1 500 trees to the acre. The trees planted in 1903 now average over 6 feet in height and are growing at a rate of about 2 feet a year. In most places the indications are that the planting will be very successful. An average of 90 per cent. of the pines are living. The cost of planting is greatly reduced by establishing a nursery and growing seedlings instead of buying them of nurserymen. Not only is the cost less, but the trees are in better condition when planted, since the seedlings are moved from the nursery directly to the field and the roots do not become dried out, as they often do when shipped. We have about one third of an acre in nursery and this spring there were 160 000 white pines and about 15 000 maple in the beds.

There is no difficulty in growing hardwood seedlings. In growing pines and other coniferous trees, more careful attention is required. The seed beds are rolled after seeding and covered with leaves or straw to prevent their drying out. Sunlight is not essential for seed germination, but when the seedlings break the ground, light is required. The beds must be carefully watched and as soon as the leaves appear above the ground the protective covering should be removed. If this is not done within two or three days the young seedlings will probably die. In one other respect conifer seedlings require special attention, that is, keeping the beds well watered during the first three months after germination. This is necessary because of the shallow root system of coniferous trees. There is no tap root as is common with hardwoods. A covering of screens which provide half shade is usually placed over the beds during the hot months to hold the moisture and inure the seedlings to shade when planted among larger trees. (See Plate I.)

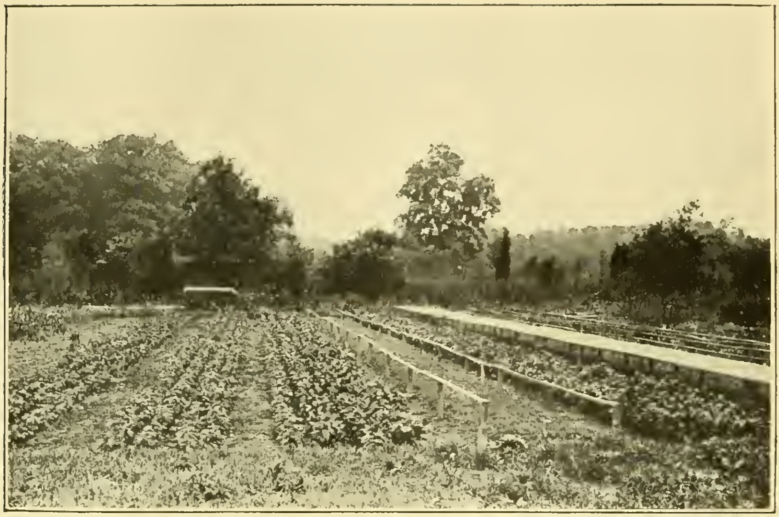

FIG. 1.

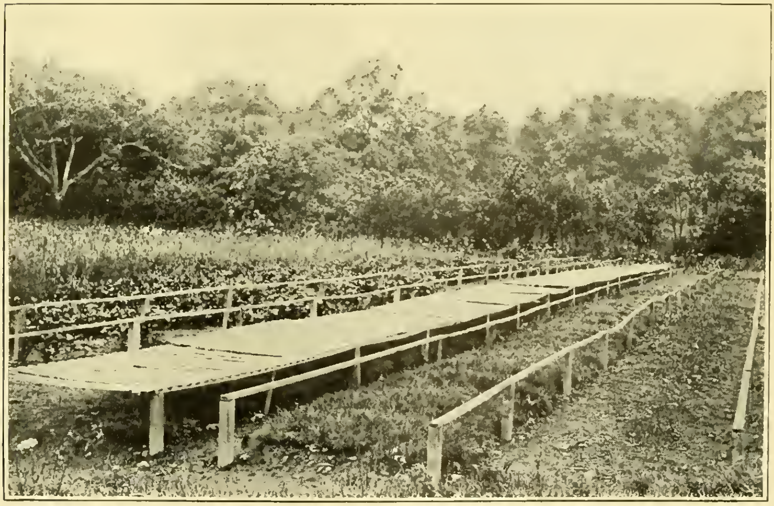

FIG. 2.

NURSERY AT WEST HARTFORD.

If larger trees are desired for planting, the seedlings are transplanted in rows in the nursery and allowed to grow a year or two before being planted permanently. Much stockier trees are obtained in this manner, but when a large number of trees are being planted it is better in most cases to use one-year stock. When the trees are to be planted in tall grass, or where shaded by older trees, it is advisable to use transplants.

Considering the difference in cost of transplants and seedlings bought of nurserymen, it is more economical to purchase seedlings. The high cost of seedlings has been one of the difficulties in the way of forest planting, but the larger numbers now being grown in the state nurseries and sold at cost has reduced the price to about $3 per thousand.

Mr. Mulford, a former state forester of Connecticut, made the working plan for the Higby Mountain Reservoir tract under the control of the water commissioners of the city of Middletown. The plan called for the planting of 168 acres. Work was begun in 1903 and up to the present time about 59 acres have been planted with 125 000 trees. Extensive planting was to be done, using pine in mixture with hard maple in alternate rows. The pines were planted and are doing well, but the maples have not been put in. The result is that the pines are too far apart on these areas to form a good stand and have so much start that unless interplanted by very rapid-growing trees they would entirely suppress them. The only species that could be safely planted between these rows is Scotch pine, which is rapid growing and tolerant enough to withstand crowding of the older white pine. White pine three-year-old transplants were used in this planting and 95 per cent. are alive.

At Middletown the planting of chestnut and oaks has been very successful, when transplants from the nurseries were used, but it has failed where seed was planted directly. Many experiments with various species and mixtures have been tried, but the results thus far seem to indicate that white pine is the best tree to plant.

The New Haven Water Company has made a coöperative arrangement with the Yale Forest School under which the land about the Maltby Reservoirs is available to the school for work of experimentation, and the school in its turn takes charge of all forestry work on the tract.

In consequence of this arrangement, a number of experiments have been undertaken. The financial results have been favorable because a good deal of the planting has been done by students for practice. Considerable underplanting with evergreen trees has been done near one lake in order to replace the present hardwood stand with a mixed coniferous and hardwood forest. The open land is being planted up as fast as the school can undertake the work. Up to the present time 100 acres have been planted.

The Ansonia Water Company has done considerable planting, largely to white pine. This company has secured instructive results in practical forestry, especially in handling chestnut ties and poles.

All of the water companies have waste land, which is producing scarcely anything. If it can be shown that the returns will pay a fair rate of interest on the cost of planting up this land, the investment should present itself as a good business proposition for water works. Of course, it is impossible to predict the future value of pine lumber, but probably prices will rise as the old timber becomes more scarce.

It costs $7 to plant an acre with two-year-old pine seedlings. In fifty years this pine should yield at least 30 000 board feet per acre at $6 per thousand, as box-board lumber. Allowing $3 per acre for thinning, at the end of fifteen years and 25 cents per year for taxes, the investment would net 4 per cent. compound interest at the end of fifty years. This calculation is made on a land value of $12 per acre. Measurements made in a natural grove of white pine at Windsor, Conn., show an average yield of 35 000 board feet per acre. If this grove had been thinned systematically, it is probable that the yield would have been much greater.

It is noticeable that white pine is the tree preferred for planting throughout the state. This preference is largely on account of its value for lumber. It grows rapidly and is suitable for planting on almost any kind of soil, even on sandy soils where most other species would prove a failure.

The prevalence of forest fires is the greatest hindrance to the practice of forestry. In fact, unless some protection is provided against fires, planting of coniferous trees cannot be recommended.

Protection can be secured by patrolling the forest during the

FIG. 1.
FOREST BEFORE THINNING.

FIG. 2.
FOREST AFTER THINNING.

dry times in the spring and fall. The patrol system is expensive and will not pay on a tract of less than 1 000 acres. A fire can be limited to a few acres by means of fire lines. It is evident that these lines must be kept free from grass, leaves, etc., in order to be of use in stopping a fire.

In recent years there have been no serious fires on the Hartford watershed. This may be due in part to good fortune, but careful lookout is kept by watchmen, whose duty it is to patrol the watershed for other protective purposes, and by other employees of the department. Forest fire laws are continually made more rigid and penalties greater, but much can be done to prevent fires by creating a change of public sentiment against carelessness in kindling fires.

Because not much wood is destroyed, most people underestimate the damage done by ground fires. Not only is the leaf litter burned, the soil impoverished, and the growth of the trees checked, but usually all seedlings are killed and the larger trees become infected with disease and decay, on account of the scorching of their bark.

The state of Connecticut has a very efficient forest fire warden service which is greatly diminishing the damage done by forest fires. The new law, requiring all persons to obtain written permission from the district fire warden to kindle fires, is a move in the right direction and time will prove its efficiency, but it certainly has increased the duties of the town fire wardens. The work of the state through the agency of the state forester and State Agricultural Experiment Station has been very effectual in arousing interest in forestry throughout the state.

The state owns over 1 500 acres of brush, forest, and pasture land in Simsbury, Portland, and Union. On this land planting and thinning has been done, not only to improve the land, but to show the people of the state what can be done by the practice of forestry. This demonstration has had a marked influence in the towns where these forests are located, and the adjoining towns in stimulating a desire to plant forests and improve woodland. It was estimated by Mr. Hawes last year that nearly one hundred owners in the state were practicing forestry. I think at least a million and a half trees have been planted. This planting by business men and farmers indicates that forestry appeals to them as a good business proposition.

The importance of forestry is becoming more generally recognized in this country as the supply of virgin timber approaches exhaustion and prices of the better grades of lumber rise in consequence. The length of time required to produce the best grades of lumber will, in the near future, restrict the source almost wholly to national and state forests, since private owners prefer to cut their forests at short intervals in order to get returns on their investment although inferior lumber only is obtained.

Our national forests contain 194 000 000 acres and the state forests nearly 3 000 000, yet three fourths of the forest land of the country is privately owned. The first consideration of private owners is profit. If forestry is not good business they will not adopt forestry methods. It is true that in this country forestry has been practiced only a few years, and no conclusive results have been reached, but in European countries forestry methods employed for many years have proved a financial success. For example, in Prussia the net returns per acre are nearly ten times what they were sixty years ago, and they are increasing more rapidly than ever. Probably the best example of forest treatment is in Zurich, Switzerland. This city's famous forest has been managed under a working plan since 1680, and is to-day one of the most perfectly managed and most profitable forests in the world. It yields on an average a clear annual profit of $12 per acre.

Different conditions in this country require different methods in applying forestry, but it is safe to assume that the results will be equally successful. European countries, which are now far advanced in the practice of systematic forestry, have passed through the same stages in relation to forests as our own country. In fact, in the case of nearly all countries, the danger of famine in lumber has been the principal cause of the adoption of forestry. It is estimated that we are cutting annually three and one half times what our forests yield. At this rate of consumption, it is evident that the present supply of lumber will not last many years.

By a conservative use of our present forest land and by utilizing all waste land by planting, it is believed that the yield can, in time, be made equal to the demand.

DISCUSSION.

R. C. Hawley, Esq.* I think you would perhaps be most interested, gentlemen, in learning how forestry can be of use to you, — what sort of a business proposition forestry is for a water company. Water companies are in a good deal better shape to practice forestry than the average person, or the average company, because the water company usually has around its reservoir considerable land which they must hold. In the case of some companies, they own the entire watersheds which surround their reservoirs. This land falls in two classes: First, a large part of it is land which is absolutely worthless for anything but the production of timber; and, second, land which was at one time cultivated and capable of producing farm crops, but which you gentlemen are becoming more and more convinced should not be used for crops around your reservoirs. Frequently, you are taking down the farmhouses and ceasing to cultivate the land. Water companies, therefore, are in the position of owning land which they can use in no possible way except for growing timber. You cannot get any money out of that land, except by producing wood crops; so, if you want to get a profit from your land, as well as from your water, you must fall back on the growing of trees.

Forestry is a long-time investment. It calls for considerable waiting, in our country, before the returns come in. Water companies have an indefinite existence, and ordinarily they have more means for long-time investments than private individuals have. Such companies are well able to make the investment which a businesslike forestry demands.

Forestry work also affords an opportunity for a water company to use steadily their skilled labor, which in certain seasons of the year is employed in the construction and maintenance of their pipe lines, — by keeping those men whom they want to retain employed in the winter time at work in the woods. How far that applies to all of you, I don't know; I know that it does apply to some companies. They are glad to have the opportunity of putting the pipe gang into the woods in the winter and covering the expense of that gang.

There is another way in which forestry should appeal to water

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* Professor of Forestry, Yale University.

companies, and that is in the line of a protecting cover to their sheds. That, of course, is an indirect benefit, — the protection which a forest affords around reservoirs, especially near roads, against the blowing in of dust from these roads, or, where there is a steeply sloping country, against the washing of silt and debris of all sorts into the reservoir. As a protective agency alone, it would often be advisable to maintain forests on these sheds.

Now in practicing forestry, what return can a water company hope to secure? Mr. Goodrich has spoken of the profits which come from a well-managed forest. These profits may range from one dollar to twenty dollars an acre net per year, on land devoted to forestry. That is something which would be secured from land which otherwise lies vacant, idle, and does not bring you in any return. But in starting forestry work I want to caution you that such returns cannot be obtained right off, unless your land is now stocked with considerable merchantable timber. Financial returns in forestry come only after your tract has been put in proper shape. A great deal of your land, undoubtedly, is sprout land, small, young woods or bare fields, and you can no more expect to get an annual return from that land now than you could expect to go out and buy an abandoned farm and make it pay you profits until it had been brought up by fertilization and proper methods of cultivation. So, in starting forestry work, the chances are that every one of you would have to anticipate deferring your profits for a period of possibly ten or twenty years, when you might expect to begin to secure small annual returns from your land.

I do not believe, however, that there is a company represented here, possessing either vacant land or forest land, which could not, by starting forestry work, assure itself of an income ranging from a few dollars to a good many dollars per acre per year in the long run from these lands; and I repeat that inasmuch as those lands are mainly lying idle, it is a good thing to take up forestry work and get an income from land which would be otherwise unproductive.

The President. We have with us a gentleman who, I understand, has had considerable experience in the practical work of forestry. I have the pleasure to present Mr. E. B. Bronson, of Winsted, Conn.

Elliot B. Bronson, Esq. *Mr. President and Gentlemen of the New England Water Works Association,* — I suppose I am asked to come here to tell you something about getting a financial return out of your by-products. I am not a water-works man, I am not a trained forester, but I am a lumberman. I agree with Professor Hawley that the investment is a long one, and yet from an experience of twenty-five years I think I may tell you that it is generally a successful one. I am not going into some of the details I expected to, owing to the lateness of the hour, but I will give you just a few concrete illustrations that I worked out from my own experience.

To show you what you can get from pine lumber land in Connecticut and Massachusetts, I will say that, a short time ago, I cut a piece of 23 acres. This was heavy pine timber which had been well cared for. I cut off 957 000 feet of lumber and 617 cords of wood from the 23 acres. There were 730 pine-trees on that piece that cut 750 000 feet of lumber. That was an exceptional piece for New England, but it was because it has been cared for by good forestry methods and was a valuable investment for the owner, and also for me.

Now, speaking of our sprout land, Litchfield County, which is the largest county in the state, contains 612 600 acres, or more, and 55 per cent. of it is sprout and woodland. Only an insignificant portion of this can be estimated as virgin forests. The forest area can be subdivided into the mixed hardwood type and common hardwoods, including chestnut, of which species there is about sixty per cent., covering about 264 000 acres, or about eighty per cent. of our forest land; the white pine type of 3 600 acres, or about 1 per cent.; and the abandoned field type, which consists of our old back pastures and abandoned farms, that, uncared for, are growing up to white birch, alder, scrub pine, poplar and hemlock, of about 70 000 acres, or about nineteen per cent.

The age in years of the hardwood type is estimated as follows:

71 800 acres, 1 to 20 years;
180 000 acres, 21 to 40 years;
9 000 acres, 41 to 60 years; and
3 200 acres, 61 years and upwards.

It is estimated that of this there are about 242 000 000 feet of chestnut and oak lumber; 80 000 000 feet of other kinds of lumber, leaving a balance of 4 300 000 cords of cord wood, with a grand total value for our forest tract of $4 512 000, or an average of $13.40 per acre for the average forest crop of Litchfield County. We, are, however, cutting this wood off so fast at the present time that in about twenty-three years, unless we do something to replenish it, it is all going to be gone. New Haven County is in a still worse condition than that. I might give you something in detail in regard to the figures, but I will not stop for that. The point I was making is that our mountain countries are your sources of water supply and they must be cared for; and, if the forests are denuded, you gentlemen, of course, know what effect it will have on your water supplies.

Now, speaking of the long-time growth of sprout land, I have a record of twenty-five years of experience of all the lumber we have cut in that time, giving the number of feet of each kind of lumber produced, cords of wood, poles and posts, and the cost of production, all tabulated, which is a valuable thing to me in my business. I took off a concrete illustration, which I thought was a fair one, of a mountain side which is on the watershed of one of our Litchfield County water supplies. My father bought the land, 43 acres, forty-five years ago, as an investment, as he said, for his children. It had all been completely cut off, — just skinned, as we say. He paid $135 for it. His children, or I, one of them, cut it off after forty-five years' growth. I cut 155 654 feet of lumber, 1 550 cords of wood, $250 worth of piles and posts, giving me a gross profit of $2 284.84. On the original cost, $135, I figured six per cent. against it for forty-five years, or $364.50; I figured the taxes for forty-five years at $202.25; then I charged $500 for my services in marketing the product, and I had left $1 118.09, or a total net profit of 855 per cent, or yearly net profit of 19 per cent., plus the 6 per cent. which I had charged on account of the original investment. That wasn't forested, that wasn't cared for, that was simply as nature gave it to us.

I have been practicing forestry for some few years, setting out trees with the rest of you. I think there were some 600 000 trees set in the year 1908 in Connecticut, and more set in 1909. I think

some 2 500 acres were set in New England by private parties up to 1908, and the amount was much increased in 1909.

I am convinced, gentlemen, that as a financial proposition, as a by-product of your water works, there is nothing that you can do, primarily to protect your watersheds but also as a financial investment, which will bring you better returns than planting trees, preferably in this section pine or chestnut, because they are the quicker growing and the more ready to help nature out.

Mr. William F. Sullivan.* The reason why I came here to-day was, that I was desirous of acquiring some information with regard to forestry. We have about 800 acres in our reservation, of which about one-fifth is water. The rest may be classified as woods, pasture, forest, sprout land, and cultivated land. While improving, thinning, and developing, the question arises how to handle the ripe or financially mature trees and the thinnings.

I have been much interested in the remarks of Professor Hawley, and especially in those of Mr. Bronson. From the latter's remarks and the knowledge he possesses regarding lumbering, I judge he will be able to show us what to do and how to do it.

Now, we are not particularly impressed with the idea of planting white pine unless natural reproduction is almost impracticable. We believe in natural reforestation, that is, by the strip method of cutting, or leaving from three to six veteran seeders to an acre. There are timber lot operators in New Hampshire — and one large operator in particular, with whom I am somewhat familiar, who has cut probably as much as any other man in the state. He, like the others, has generally bought the land and stumpage and has never practiced modern methods. He has never safeguarded his own interests by permitting any seed trees to be left on a cut-over territory, but has always slaughtered the forests by cutting off every tree. Well-informed people and authorities in forestry and the lumber business say that if this man had left a few seed trees per acre on the vast tracts which he has cut over, the present value of this land, which is now a barren waste or covered with a worthless growth of scrub oak, would be more to-day than the gross receipts from all of his lumbering operations.

In regard to the kind of wood, we believe that white pine will be

*Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

the most profitable. We are cutting off the hard woods. We find in many instances oaks which show from seventy to eighty years' growth from stem analysis, to be about six inches in diameter. Their growth is too slow. Then again, the browntail moths have invaded our forests, and the cost of extermination without cutting is prohibitive. Some of our pine timber land will cut from 21 000 to 57 000 board feet per acre. We have at the present time about 2 000 000 feet on the stump, and, according to our survey, we ought to thin out about 300 000 feet. Of course as a water works we are interested primarily in the forest cover. That was the original object in acquiring these forests. But now we feel as if the time has arrived not only to reproduce and develop the white pine forests but to study the financial status of our forests.

When we take it up as a money producer, how are we going to handle the product to the very best advantage, with the factors usually to be found in a water works, such as men and mechanics available at times, undeveloped water power, and an organization that will not add much if any expense to the supervision and selling?

If we employ a portable sawmill outfit, at a low cost per thousand, they will want to cut ruthlessly and slaughter the wood lot, for they are simply working at top speed for the little profits there are in it. If we can utilize our seasoned men to an advantage at such time when they are unemployed, — for we believe we can do as Professor Hawley says,— we can do the work more carefully and with less injury to the pine undergrowth. When the thinning is completed, even if the cost is a little more per thousand, the difference in cost is more than offset by the increased value of the remaining immature trees on the cut-over area.

Speaking of the factor of men in a water-works outfit, we all know that it is important to keep faithful, intelligent, and able workmen employed during as many months of the year as possible. One cannot expect to call upon men that were laid off in November and get a free response on a cold night in January, when there is a bad break or a difficult job in a cold, wet, and nasty place.

The particular problem we are endeavoring to solve, while not of the greatest import, nevertheless requires some study and practical information. Is it advisable to put in a portable steam

Fig. 1.

First Stage, White Pine Improvement. Note the Fire Hazard.

Fig. 2.

Second Stage, White Pine Improvement. Burning the Brush.

Forests of the Pennichuck Water Works, Nashua, N. H.

mill, a stationary steam mill, or, as we have an undeveloped water power which requires only the installation of a short length of penstock and a water wheel, shall we put in a water-power mill, the total cost of such an installation not to exceed $3 000?

Our first valuation surveys show that we have at the present time 300 000 feet of trimmings to cut, which cut will improve the remaining trees; that the natural increase in growth at the present time is 60 000 feet annually, and will increase from year to year. Now, I ask you, gentlemen of the Association and the lumber men present, can we advantageously put in a $3 000 water-power mill on the hitherto undeveloped water power?

That brings up the point of the former condition of things in our locality, and, I might say, throughout New England. Not so many years ago, every village and town had its gristmill which ground the corn of the miller and his neighbors, and a sawmill to which they could bring their logs and have them cut into boards or dimension stock, paying in cash or leaving a portion of their haul in payment. They could do it then, when corn and timber were cheap. The West and Northwest could afford to sell and ship the meal in competition, and did so. Times have changed — high prices everywhere. Freight rates have come to be a question which almost every farmer is able to understand and discuss. With the prevailing high prices, why cannot the large and small farmer and land owner come back to his own? I ask where have the mills gone to? Abandoned! We ourselves have been guilty of dismantling at least three such mills and throwing the machinery to the junk pile, allowing the water to pass over the dams without turning a wheel. I believe that "history is going to repeat itself," that the New Englanders will see the light, and that most of us are being educated to the idea that we can grind our own corn and saw our own timbers and get the highest price without too many middlemen's profits.

One of the items of profit which is unusually consumed in steam mills is the slabs. Every 3 000 to 5 000 board feet cut will yield about one cord of slabs, and slabs are worth in our part of the country $2.50 per cord on the cars. Here is a by-product which can be saved by a water-power mill. Water-power mills also eliminate the fire hazard to a very large extent.

I am somewhat concerned to get the benefit of the experience of you water-works men and our friends the conservationists and the lumber men present to-day. I want to find out if it will pay us to put in a water-power mill and go back, as it were, to the prosperous old times, take in such of our neighbors who have jags of timber to be cut into boards or stock, we doing it at a reasonable price, and get the slabs in part payment. Who has not seen the blighted territory with its mound of sawdust after the march of the portable mill, the forest devastated and slashed, the undergrowth largely destroyed?

In the past, farmers and landowners, burdened with mortgages, would sell the stumpage to some operator, and would not realize even a fair price. If he sold his logs, they were scaled by any of forty different log rules for board feet, such as New Hampshire, Scribner, Doyle, etc. Many of these rules, according to the Bureau of Forestry, " are admitted to be inaccurate and unfair by their users, who continue to employ them because a satisfactory rule is not known or is not readily available." " Satisfactory log rules are difficult to construct because the sawed product of logs depends upon the skill of the sawyers and on the kind of machinery used." So you see, gentlemen, the fellow who sells the logs without knowing the rule has been sort of " trimmed," to put it mildly.

Now, when the fellow who owns the logs brings them to the adjacent mill, and dickers for terms, after allowing for the kind of machinery and saw, he gets his logs into boards which have a standard of measurement as sure and positive as the United States standard of weights and measures, also a market country-wide, which makes him independent of a purely local market and enables him to realize much more.

To hark back again, my point is this: Will it pay us to put in a stationary mill, and to cut with our own outfit the 300 000 feet of already ripe timber? If we do this, we can periodically thereafter cut the annual yield, which is at present 60 000 feet, and will increase yearly, and cut the logs our neighbors may bring. I am trying to find out if it will pay, and I believe that Mr. Bronson who has had such a large experience as an owner and operator, is the one who is going to enlighten me on this, to us, very important matter.

Fig. 1.
Third Stage, White Pine Improvement.
"Woodman, spare these Trees."

Fig. 2.
Fourth Stage, White Pine Improvement.
Woodman, do not spare these Trees.
Forests of the Pennichuck Water Works, Nashua, N. H.

FIG. 1.
WHITE PINE REPRODUCTION, SIXTEEN YEARS OLD.
NOTE THE HALF DOZEN VETERAN SEEDERS.

FIG. 2.
WHITE PINE PLANTED IN 1896. NOTE THE TEN-FOOT SCALE HELD ALOFT BY A SIX-FOOT MAN, ALSO THE YEARLY GROWTH AS SHOWN BY THE SWIRLS.
FORESTS OF THE PENNICHUCK WATER WORKS, NASHUA, N. H.

Mr. Bronson. Mr. Sullivan, you have my sympathy. [*Laughter.*] I have had water mills and I have had portable mills and I have had stationary mills. I think it all depends upon your situation. If you have got to haul your 300 000 feet any considerable distance to a mill, I shouldn't put up a water mill. Buy a portable mill for from $1 000 to $1 400, and then you can control it and handle it in such a way as to protect your timber land. The slab question is something to be considered, yet the value of the slabs will be eaten up, and more too, in the cartage of your logs to a water mill, if the distance is anything considerable, — that is, a mile or more. I would hardly think you could afford to put in a water mill unless your neighbors have a good many logs to bring in, if you have only 300 000 feet now and 60 000 feet a year to cut — for it would cost only $3 000 to construct and then you would have to maintain it. But I do think you can take a small portable mill, which you can move around upon your property from place to place as you need it and handle with your own men, and that it will pay you well for the investment.

Mr. Sullivan. We have also looked at this phase of the question: Running through our lands is a chain of ponds, and there is an undeveloped water power. Adjacent to and on the slopes of these ponds are our pine forests. We can put our men on, cut and dump the logs on to the ice or into the ponds, for we do not use the water for our water supply, only for power purposes, — so we wouldn't have to do much teaming, only skidding; then float them up stream or down stream to the proposed mill located about midway on our chain of ponds. As you are no doubt aware, if you cut a lot of logs and leave them lying about without mill capacity, the borers will get into them and destroy the market value. Then if fire should burn over a large territory, and we have a mill right at hand, we are able thereby to obtain the highest possible per cent. in salvage. Again, we cut our trees, dump them into the pond, and cut them when we have a surplus of water and men. That is utilizing our water power and utilizing our men.

Mr. Bronson. I agree with you, Mr. Sullivan. The only fault I have got to find with your project is, you haven't got timber enough to pay you for carrying it out. Sixty thousand feet of lumber yearly would cost you, possibly, $300 to get to your mill;

and can you afford to put up a mill for $3 000, and handle it in that way, for $300 a year's saving? Probably you would save something by putting the logs into the pond and floating them down, but 60 000 feet is a very small amount of lumber to care for, and 60 000 feet of logs would make a very small showing in any pond; in fact 60 000 feet of logs would go into this room very nicely.

Mr. Sullivan. We are a little altruistic up our way, and believe in doing something for our neighbors who are being fleeced right and left by some of the lumbermen by means of the pernicious log rule.

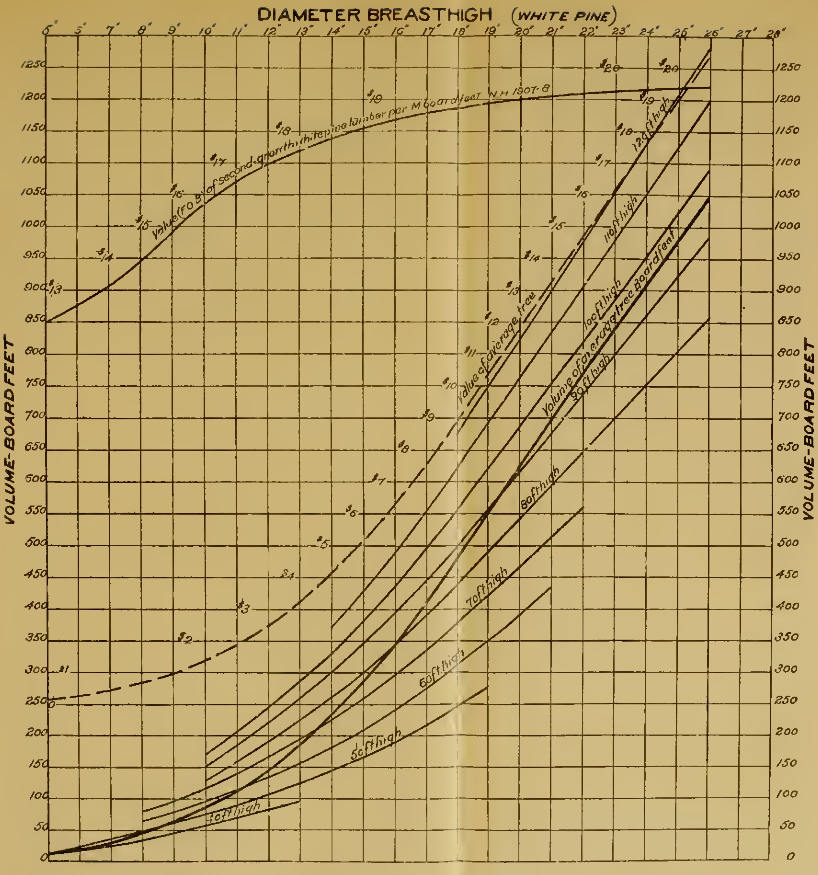
Mr. Bronson. By all means put in a mill then.

Mr. Sullivan. I want to have this matter discussed fully. While gathering information, I made some charts to familiarize myself with regard to values. I don't know whether others would consider them worth anything or not. I brought them down here to show to any members that might be interested. One chart shows (Plate III) the volume board feet of trees from 5 inches up to 26 inches B.H.,* and from 40 to 120 feet in height, age about seventy-five years, also volume and value of an average tree. The upper curved line indicates the value (f.o.b.) of white pine lumber per thousand board feet.

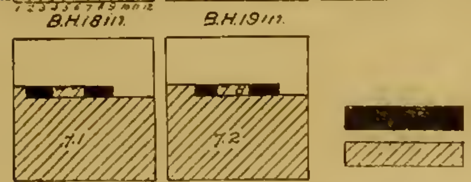
The other chart (Plate IV) shows diagrams of relation between volume of used length, with bark, in cubic feet and actual mill cut, in board feet, — white pine fifty to seventy-five years of age. Band saws cut a kerf one-eighth inch, circular saws cut a kerf one-quarter inch. Also the chart shows volume and value of average white-pine tree, and per cent. increase in volume and value for each inch growth in diameter B.H. The lower charted lines show the net increase board feet and the net increase in value for each additional inch growth in diameter B.H.

Gentlemen, I don't know whether they are worth much. They are compiled from "Forestry Reports" and may not have been culled from the knowledge boxes of the big lumber operators, for when you try to pry into the secrets of lumbering, you are mostly up against a set of closed books. Many of them are very successful lumbermen, but they keep their knowledge in their heads.

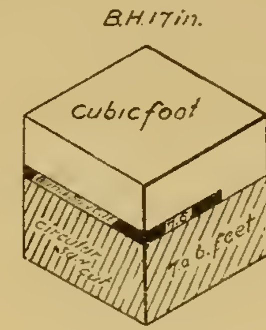
* Breast high.



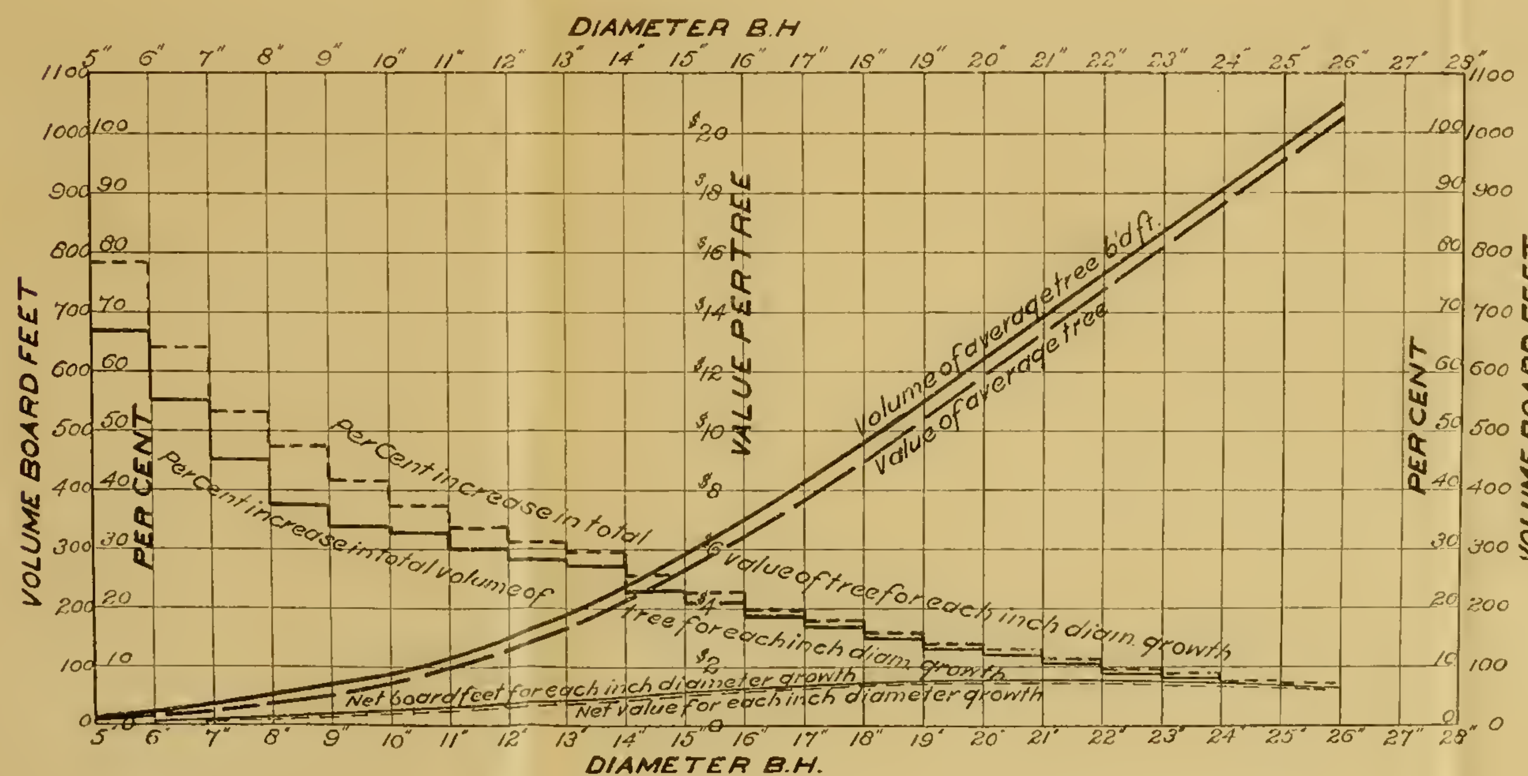
This chart shows the volume, in board feet, of trees from 5 in. to 26 in. B.H., and from 40 ft. to 120 ft. in height, age about 75 years. Also the volume and value of an average tree. The upper curve indicates the value (f.o.b.) of white pine lumber, per thousand board feet. Compiled and charted from data in "Reports of N. H. Forestry Commission for the years 1907–1908." Pennichuck Water Works, Nashua, N. H., March, 1909, W. F. Sullivan, Superintendent.



Diagrams showing relation between volume of used length, with bark, in cubic feet and actual mill cut, in board feet, — White Pine 50 to 75 years of age.



Explanation



DIAGRAM

Showing volume and value in average **WHITE PINE** tree, also the per cent increase in volume and value for each inch growth in diameter B.H. The lower charted lines shows the net increase board feet and the net increase in value for each additional inch growth in diameter B.H.

Compiled from authentic information in N.H. Forestry Reports and from Forest Measurements by C.A. Lyford.

Note:- Solid lines represent volumes.
Broken lines represent values.

Pennichuck Water Works
Nashua N.H.
Mar. 1909. W.F. Sullivan Supt.

They seldom use pencils. They go to a piece of timber land and, with their long experience and accurate knowledge at lumping, can place a value and obtain the timber, skin it, and their bank account generally shows that they made a good thing on the transaction. They seldom say how much. I do not blame them. They have devoted a lifetime in acquiring such knowledge. So, if you can find out from the lumbermen in New Hampshire whether the industry is a paying investment or not, you will do better than I can, gentlemen. I don't know about the Connecticut men. Certainly, Mr. Bronson has the information and he is generous with it here to-day. We outside the inner circle are in the pioneer stage, seeking useful knowledge pertaining to forestry and its branches, especially harvesting. We are into it and I don't know how we are to get out of it.

Foresters say that, " to obtain the largest returns from an investment in growing timber, it should be cut when it is financially mature. This is when the per cent. of increase in its stumpage value begins to fall below the interest rate obtainable from another investment of equal security." This principle of financial maturity works out thus in our forests, — that trees full grown have not a uniform diameter. Trees of equal height and age range from 8 to 26 inches diameter, breast high. I believe other things besides diameter determine the mature tree. The parasite and moss-covered tree, the tree afflicted with bores, the dying tree, and the financially mature tree, should be harvested at the proper time, like any other crop.

Do we not see from this the necessity for the individual or concern which has much growing timber to be ready with the facilities for harvesting?

Professor Hawley. Our experience has been that water company's men, while they can calk pipe in great shape, know about as much about working in the woods as some of the clerks in the stores. If any water company starts in to use their men in the woods, they have got to expect, I think, for the first five or six years to lose money on the proposition, because they may not be able to handle the woods work economically.

I want to disagree with Mr. Bronson a little bit on the mill proposition. It seems to him, he says, that you don't want to put

in a water-power mill, and he thinks you had better buy a portable mill. Now, if you are going to do anything on the mill question, I would advise putting in a water-power mill or renting a portable mill. I don't know just how it is up in New Hampshire, but in the southern part of Connecticut it is certainly an easy proposition to rent a portable mill. We find that we can get the most from our timber by renting a mill, having the sawing done at so much a thousand by the owner of the mill, and checking him up to see that we get what he saws. I would recommend renting a mill as the cheapest for the present. Or else, instead of putting in a portable mill, putting in a water-power mill. Since the tract contains a string of ponds, furnishing cheap water transportation for logs, it would be possible to bring the logs to a water-power mill, situated on one of these ponds, without heavy costs for teaming. It seems to me that a stationary water-power mill would be cheaper to run and keep in repair; and being more carefully housed would last longer than a portable mill.

Mr. Sullivan. I must take issue with the professor with regard to the labor question. We thoroughly believe in reciprocity with Canada, and we have some of the best French Canadians in Nashua I ever saw. They are all natural-born woodsmen, and what they don't know about wood cutting and harvesting isn't worth knowing. I am only an infant in this matter. They have opened my eyes, and shown me a great many things. We have had the government forester up there, and he said, "Those fellows know their business." That is the kind of labor we have, and they know the wood business and the forestry business from A to Z — that is, without the technicalities which are now thrown around it. They can tell you almost anything you want to know. They are certainly able to cut and saw and take care of the by-products and all that, and as for harvesting cord wood, you can't beat them.

VIBRATION IN HOUSE SERVICES.

TOPICAL DISCUSSION.

[*March 9, 1910.*]

The President. The members have been requested to present verbally any practical questions for discussion, and any member having anything he would like to bring up for discussion now has an opportunity to do so.

The following question has been presented by letter from Houlton, Me.

"We have a Goulds Triple-Geared Pump with rawhide pinions installed at our station, capacity 1 000 gallons per minute. We are very particular to keep all the valves in good order, but are troubled with a vibration, which sounds like the gears on the pump, in the residences located on the two 10-inch mains within 1 000 to 2 000 feet from the pumping station. On some services it is hardly noticeable, while on others it is very annoying. We have tried pressure reducers and air chambers with a little effect, but they do not remedy the trouble."

Can any one tell us what the trouble is at Houlton?

George F. Merrill.* I suggest the possibility that the air chambers they have may be too small. We had the same experience on our pump at Greenfield. We found that the air chamber would fill with water, but by forcing air into it with an air pump we partially overcame the trouble.

Samuel A. Agnew.† I would like to know where that water comes from. Is it from driven wells? I have had some trouble with my pumps that way, and have always found air in the water. As soon as the air came along, the gears began to rattle, but as soon as I got the air out of the water the rattling of the pumps stopped. I have noticed this in my pumps especially when the vacuum is running high — 25 inches or thereabouts.

Mr. F. H. Hayes.‡ One of the troubles we have found in our

* Superintendent of Water Works, Greenfield, Mass.
† Superintendent of Scituate Water Works.
‡ Of the Platt Iron Works, Boston, Mass.

pumping station has been obviated, as Mr. Merrill says, by putting on air chambers and putting them on large enough. That helps a little, and then, as Mr. Agnew says in regard to air coming in with the water, if the chamber does not fill the plunger of the pump will hammer, and the hammering may be what is the trouble, possibly, more than the noise of the gears. Sometimes an air pump, by forcing air into the discharge chamber, will overcome that trouble, but the rawhide pinions ought to stop some of it. Is it a direct connected pump?

THE PRESIDENT. "Triple-Geared Pump" is all the letter says.

MR. HAYES. Do you know how it is driven?

THE PRESIDENT. I do not.

MR. HAYES. We have considerable trouble where we have had direct-connected pumps, that is, with an end gear from the motor, and we have overcome that with belting.

CHARLES N. TAYLOR.* This discussion interests me, because I have the same trouble. I am interested in a system of water works at Orono, Me. The pump is run by an electric motor. It has been installed about four years and we have had a great deal of trouble like this. We have enlarged our air chamber and now have a very large one, so that our trouble is not as great as it was. But at times the pounding is so great that on some lines the customers have to shut off the water at night in order to be able to sleep in the houses. I have another system at Milo, Me., and a few days ago I got a letter from a customer stating he had been obliged to shut the water off entirely, as he could not endure the noise. He had just had a new copper boiler put in and the pounding was so severe it pounded the top of the boiler right off. The worst trouble is on the higher level, where the pressure is the least, as the air evidently gets up there. Three boilers are said to have burst on this one street, although they had been tested to 200 pounds' pressure before they were installed. The nominal water pressure is only 40 pounds on this highest street, although at the pumps we have a pressure of about 100 pounds. I have been almost helpless to know what to do in regard to this trouble and I hope to get some information this afternoon regarding it.

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* Contracting Engineer, Wellesley, Mass.

Frank L. Fuller.* There was considerable trouble at Marblehead at one time. We had a duplex pump of about 1 000 000 gallons' capacity, and when the pump was in operation there was a great deal of noise at a point two miles away. I don't think the trouble lasted a great while. In the upper part of the building of the Forest River Lead Works, which was on this same system, there was a great deal of pounding in the distribution system which was, I think, of 1-inch pipes.

They tried in every way to get the air out of the system, but the trouble continued for a long time though eventually subsiding. These troubles are, I think, difficult to locate and the cause is often hard to determine.

In my own house at Wellesley I have had periods when the pipes would "chug," as we call it, and rattle so that it would be very uncomfortable and unpleasant. I presume it is due to an accumulation of air, and after a while the trouble works out and the noise ceases.

George F. Merrill. The way our trouble was partially obviated was by tapping the air chamber and putting on a gage to indicate when the chamber was full of water. We found that the air chamber would fill with water in about an hour's time and would then lose its efficiency. When this happens we force air into the chamber by means of a combination of check valves on the water end of the pump cylinder.

Mr. H. L. Thomas.† We have experienced precisely the same trouble that has been spoken of; like complaints of noise in the service pipes have come to us, and in a few cases occupants of houses have been greatly alarmed. We were at first perplexed to know the cause of the disturbance, and not until we took steps to put a water-column glass on the air chamber of the pump did we discover that this air chamber was filled with water. We have overcome the difficulty by admitting air into this chamber as often as necessary through a pipe connecting with the compressed-air starting outfit used in connection with our gas engine. Very recently, in response to a complaint that service pipes were again rattling, we found that through neglect on the part of one of our

* Civil Engineer, Boston, Mass.

† Assistant Superintendent of Water Company, Hingham, Mass.

engineers the air chamber had become filled with water as before; this was promptly forced out and the noise ceased.

Mr. Hayes. If suggestions are in order, I would not follow out Mr. Merrill's idea, for if you introduce air into the suction, the plunger is liable to suffer. If the plunger hammers, it goes all through the system. It is a matter of experience and experiment to know how much air you are carrying in the chamber, but you get better results by putting the air directly into the air chamber on the discharge than you do by letting it through the plungers.

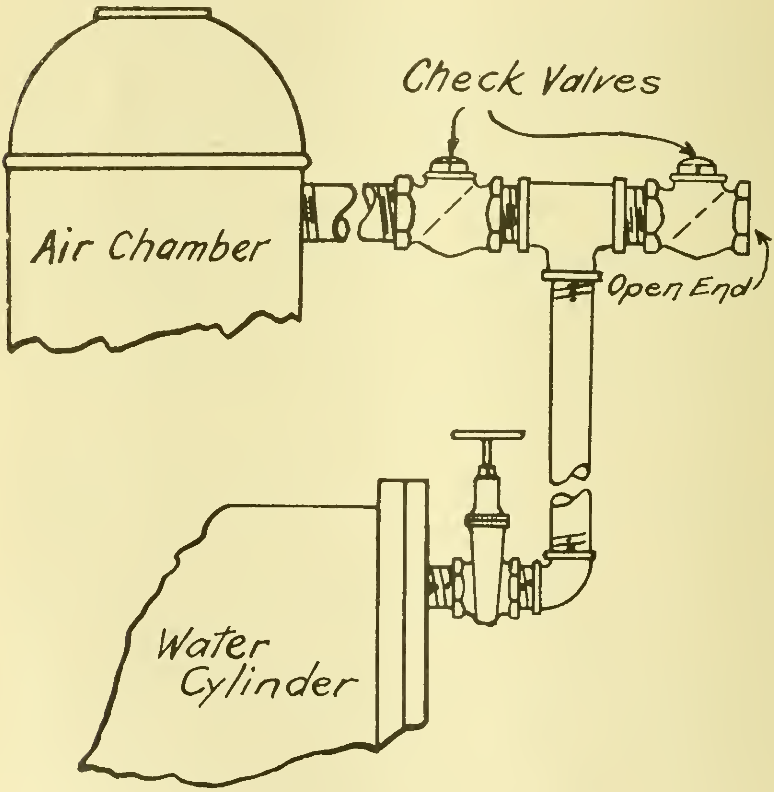

Fig. 1.

Arrangement of Check Valves to take Place of Air Pump.

Mr. Merrill. I think the gentleman does not understand just how we piped the pump to accomplish the result. The water end of the pump cylinder was tapped, and a pipe with a gate valve was connected. This pipe was extended up to about the level of the top of the air chamber, connecting into a tee, with a check valve on either side, the branch from one side of the tee was connected to the air chamber and the other left open to take in air (Fig. 1), with the result that when the pump is running, if the gate valve on the water cylinder of the pump is opened, as the pump makes a suction stroke it takes in air through the check valve, and on the return stroke the check valve closes and the air is forced into the air chamber of the pump. In operation, a little water is forced out into the pipe which is forced up and down with each stroke of the pump and acts as a plunger. The gate valve can be gaged so that a very small amount of air can be taken in at each stroke. You can get the result without an air pump in this way.

A. E. Martin.* I don't believe that all these troubles are connected with pumping systems, for in Springfield we have this same chugging that Mr. Fuller has spoken of in Wellesley, with our gravity system, but I think perhaps more of those troubles are connected with pumping than with gravity systems. In our cases we almost invariably find that some ball cock is loose and its dancing up and down causes the chugging in the house.

Mr. R. C. P. Coggeshall.† I have had a similar experience. Our department workshop in New Bedford is located about 1 000 feet from the power house of the local electric railway company. Their feed-water supply is delivered into a large tank, the delivery being controlled by a large ball cock. At one time we were experiencing frequent abnormal shocks, which were not only recorded on the pressure gage, but the noise from them could be distinctly heard at the shops. We suspected that this ball cock might be out of order, and, on investigation, this proved to be the case. It was rectified, and the trouble ceased. There is no doubt but that a difficulty of that kind will cause a great commotion on a gravity system.

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* Superintendent of Water Works, Springfield, Mass.

† Superintendent of Water Works, New Bedford, Mass.

ROUND MULTIPLE AND STRAIGHT-READING REGISTERS FOR WATER METERS.

TOPICAL DISCUSSION.

[*April 13, 1910.*]

MR. GEORGE A. STACY.* *Mr. President,* — I would like to inquire what advantages a round multiple register for a water meter has over a straight-reading register, and, if there are none, why that kind of a register should be used. I think we should not tolerate anything about our works that inconveniences us, when there is something else presented which is decidedly an improvement. I cannot see, therefore, why we should be asked to use a multiple dial on the register of a water meter, when we have a straight-reading dial that does not present any of the complications or difficulties in reading which we have with the other.

I do not think any drummer would care to go into an engine room where the engineer has a straight-reading register for the revolution counter of his engine and ask him to substitute a multiple dial, where he would sometimes have to use almost higher mathematics to find out how many turns his engine had made.

If the two dials were to be put on the side of a wall, with good light where they could be easily read, I think that there would be no question under these conditions as to which we would use. When we come to consider, therefore, the position in which most meters are apt to be put, with the bad light and all the other difficulties of reading, it has always been a wonder to me why the meter salesman should even suggest the use of a round multiple dial.

MR. J. A. TILDEN.† *Mr. President and Gentlemen of the New England Water Works Association,* — Speaking for meter manufacturers in general rather than for myself or my company in particular, I should say in answer to Mr. Stacy's question, that as a simple business proposition we try, if we make two types of a

* Superintendent of Water Works, Marlboro, Mass.

† Of the Hersey Manufacturing Company, Boston, Mass.

thing, to find out which is wanted, particularly if preference is anywhere near evenly divided. There is a large difference of opinion upon this question; for the round dial still has a great many warm friends; while a great many people prefer the straight-reading dial. That is why we ask whether dials shall be the old style round reading, or straight reading, for we, as manufacturers, feel obliged to find out what kind is wanted and to be ready to furnish it.

It is very true that some of the companies incline to one kind and some to the other, and so unless a particular kind of dial is specified with the order, one company will send out round dials and another company will send out straight-reading dials. Oftentimes it resolves itself merely to a question of judgment as to which kind is really wanted.

Mechanically, of course, there is this difference. The old round-reading dial is a perfectly simple piece of gearing, an entirely rudimentary piece of mechanism. There is nothing to it but a plain train of gears.

The straight-reading dial, on the other hand, operates on an intermittent system, or what is called a mutilated system of gearing; that is to say, the teeth are not continuous all the way around the wheels as they are in the simple round train, but are mutilated, several of the teeth being missing, thus giving the intermittent motion. This form of gearing is not as simple as the plain train, and under certain conditions is more liable to be clogged by dirt and by corrosion. The old plain round train will therefore operate, and will continue to operate, as you all know, under conditions which will put the straight-reading train out of business.

There are other conditions, however, under which the straight-reading train will work satisfactorily for years, and that is where the gearing is thoroughly protected from dirt, corrosion, vermin, and moisture. These conditions presuppose that, among other things, the dial glasses shall remain intact, and I imagine that one of the reasons why Mr. Stacy has met with success in using straight-reading dials is because he has been careful to see that broken glasses are promptly replaced.

Coming back now to the first proposition, a meter manufacturer

furnishes one man with round-reading dials because he likes them — very likely because he has found them very nearly fool-proof except for reading, as Mr. Stacy has just called to your attention; and he sells to another man straight-reading dials because perhaps he makes it a point to see that they have rather more than ordinary care.

THE PRESIDENT. The man who reads the meters for our department has complained that with the straight-reading dial when a figure is partly over he cannot tell what the reading is.

CLEANING WATER MAINS.

TOPICAL DISCUSSION.

[*April 13, 1910.*]

Mr. E. C. Brooks.* *Gentlemen,* — As some of you probably know, I gave at a previous meeting our experience at Cambridge, which was very slight. I understand that the practice of pipe cleaning prevails quite extensively in the West and in the South; and in those sections very long lines of mains have been successfully cleaned and at a very trifling cost, compared with the cost for relaying.

We in Cambridge have only had the experience of cleaning 1 800 feet of 6-inch pipe, which had been in use for about thirty years. It was cleaned at a very slight expense and very effectively. I see no reason why the practice could not be well applied to a great deal of our pipe in New England, especially in the older works. I might say that we have a supply conduit some three miles in length with which we are contemplating doing something of this sort during the coming season, should we be fortunate enough to get an appropriation for it. I think it can be very easily demonstrated that it would be money well invested.

Mr. F. A. McInnes (*by letter*).† Boston's experience in cleaning water pipes by machine was in 1884, long before my connection with the water department. I have gathered the following facts in regard to the experience gained at that time. The pipes were cleaned satisfactorily, and their capacity to deliver water was greatly increased, but the expense was prohibitive. The greater part of this expense arose from the fact that every service pipe was clogged up in the operation. Another trouble was that the machine then used would not pass through gates or Lowry hydrants on the line of pipe. No doubt this difficulty would not obtain with a modern machine. As a man who worked on the cleaning expressed it to me to-day, " It took an army of plumbers

* Superintendent of Water Works, Cambridge, Mass.
† Assistant City Engineer, Boston, Mass.

to follow the work." Personally, I have no doubt that pipes can be successfully cleaned by modern methods when the material to be removed consists principally of silt, mud, or something of that nature. There is more doubt, however, of the economy of the process when the material in the pipe is largely composed, as it is in Boston, of tubercles partly formed from the metal of the pipe together with sedimentary deposits. In our case, the material scraped out would be harder and much more likely to make serious trouble with services than would be the case if the iron were less affected by the water.

I was informed this summer by officials of the Louisville, Ky., water works that pipe cleaning is an unqualified success in that city. They now do the work themselves at a cost materially less than that charged by the pipe-cleaning people.

Mr. Brooks. I would say, Mr. President, in regard to stopping the services, that this street where the main was cleaned is a residential street, and I do not think we had trouble on more than three or four supplies on the street. That trouble was only temporary. It was easily remedied by putting a force pump on to the faucet and forcing the material back into the main.

Mr. McKenzie. I want to ask Mr. Brooks if there isn't any trouble from this pipe-cleaning machine catching on the plugs that as a rule project an inch or half an inch inside the pipe.

Mr. Brooks. The sheet steel scrapers of the pipe-cleaning arrangement which was used were so arranged that they would bend and give way before the end of any service cock, and we had no trouble at all. There were many supplies in the street, and there was no instance of any damage to any one of them in any way, shape, or form.

Mr. F. T. Kemble.* I would like to ask Mr. Brooks whether he found any tuberculous growth in any of the pipe he cleaned?

Mr. Brooks. I should day there was nearly a tip-cart load of tubercles came out of this 6-inch line.

Mr. Kemble. I had an idea that anything which would take off the tubercles might trouble the corporation taps, but it appears that it didn't.

Mr. Brooks. You understand that now, in scraping, they

* Secretary New Rochelle Water Company, New York.

allow a good generous jet of water to flow through, and, in fact, in most cases they drive the scraper with the water pressure behind, and that tends to keep the light stuff going ahead very rapidly. Unless there is water being drawn, or the attempt is being made to draw it from the main at the time, I don't see that there is much tendency for the material to be drawn into the supply pipes.

Mr. Kemble. Did you use one of these pipe-cleaning crews, or did you set up a plant of your own?

Mr. Brooks. The company sent their men.

Mr. Robert Shirley.* I saw them cleaning pipe out in Louisville, and it was mostly mud which came out of the pipe. There was so much of it that I asked if it was a sewer. So the gentleman with whom I was speaking took me one side and said, "Between you and me, the people think it is a sewer, but it is really the water main. [*Laughter.*] I saw them get out a baseball and a bat [*laughter*], but the most of the material was mud and silt.

Mr. Allen Hazen.† A few years ago I had an opportunity to see the work of pipe cleaning carried out on some pipes which had been cleaned through a long term of years. I also had an opportunity to study these pipes and note about what they were doing. The coating had largely disappeared with repeated scrapings, and the pipe corroded rapidly and the cleaning had to be repeated at frequent intervals in order to keep up the carrying capacity.

One of the most important things connected with the procedure was that part of the iron that became corroded always went into solution in the water. This iron came out in the services in the city, producing what is called the "red-water" trouble, and in this case it was rather serious. Cleaning the pipes seemed to be clearly an important contributing cause of the red-water trouble in this case.

Theodore A. Leisen, Esq.‡ (*by letter*). The Louisville Water Company, of Louisville, Ky., has cleaned over one hundred miles of water mains during the past two years. This work embraces mains varying in diameter from 4 inches to 16 inches, the

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* Of the Chapman Valve Manufacturing Company, Indian Orchard, Mass.

† Civil Engineer, New York City.

‡ Chief Engineer and Superintendent Water Company, Louisville, Ky.

greater part of the work having been confined to 4-inch and 6-inch lines. Part of this work was done under contract with several different companies and part by the regular force of the water company.

Owing to the excessive turbidity of the Ohio River water a large amount of silt was deposited in all of the water mains throughout the city, and as the filter plant was placed in successful operation in July, 1909, it was thought desirable to clean the greater portion of the distribution system for sanitary reasons, and it was also found necessary to clean them in order to provide a better supply in many sections of the city, both with a view to fire protection and for general purposes. The results have been very satisfactory, as the carrying capacity of the mains in many cases has been more than doubled, actual tests having shown a gain of from twenty-five per cent. to over one hundred per cent. in the flow through mains after cleaning. While the removal of the silt was the main object sought for, it has been found that a large amount of tubercles have been also removed.

The work of cleaning does not appear to have materially damaged the inner coating of the pipes, as evidenced by some sections cut out after the operation of cleaning, which show a comparatively clean well-coated interior. No trouble has been experienced in damage to the taps or ferrules. There has been some trouble in having the service pipes clogged temporarily after cleaning, due principally to the fact that the services were opened during the time of actual operation, thereby tending to draw a mass of tubercles into the service pipes. Where this has occurred a force pump on the service pipes invariably removes the material, thereby remedying the trouble at a very slight expense.

SECONDARY WATER SUPPLIES, THEIR DANGERS AND VALUE.

TOPICAL DISCUSSION.

[*April 13, 1910.*]

Mr. E. E. Lochridge.* *Mr. President and Gentlemen of the Association,* — All that I will attempt to do to open this discussion will be to make a statement in regard to what these secondary supplies are, and then let some of you who have had a great deal more experience with them than I have had say something about them.

The secondary supplies to which objection is raised are those supplies which are taken from unprotected or polluted sources and pumped directly into the same mains that are used by the city for their regular supply pipes, thus bringing in the possibility of the use, by regular consumers, of a water which is unprotected and usually polluted. A city may spend several hundred thousand dollars to develop a very clean watershed, guarding against all pollution as we do in Springfield, and then filtering besides, so as to obtain a water which we want to be regarded as thoroughly safe at all times. There are within the city, along some river or other water courses, several factories which are willing to take all the water they need from the city and pay for it, but which have their system of piping within the mill supplied, perhaps, from a polluted source which is separated from the pipes which furnish them with the city water only by a check-valve. They pump this polluted water against this valve in case of fire, which is the demand on the part of the insurance people, or for the purpose of securing additional water for a portion of their use. If, for example, the city pressure is 60 pounds, and the fire service to be developed is 100 pounds, when this pressure is developed by the pump taking the water from the river or other unprotected supply, the check-valve is closed, as the pressure is greater on the mill side.

In the case where the city pressure is ordinarily high enough for

*Chief Engineer, Springfield Water Department, Springfield, Mass.

fire protection, as it is in Springfield, but drops down occasionally, as it has twice during the past year, they would again be required to put up the pressure of water against a check-valve so as not to pump it through the mill and outside.

The objections to this system come in the seating of this valve. You all know the way in which any valve will seat, even a valve with carefully prepared faces that have to be driven home. Tubercles and growths, or any small stick, refuse, stones, or sand, which get into the pipe at the time of laying, or at any other time, getting on the face of the valve will prevent its perfect closing. This has been obviated in part, in recent years, by a system of double check-valves. We have none of these in Springfield, so I cannot speak very intelligently as to their practical working. I think in practice there will be none to deny that the old check-valve is a fairly dangerous mechanism.

Here we have, then, the matter stated simply: The piping in the mill is the piping through which you must furnish them the water. The mill is required to have an additional supply, on account of the insurance rate, and the question becomes purely one of expense, as to whether those same pipes within the mill should be utilized for the fire supply, and if so, whether they should be supplied with pure water which you can furnish, or see that is furnished, as a secondary supply, or with a polluted water. The question then, to state it broadly, is simply one of fire protection.

What then, can be done to enable this secondary supply to be used, and what can be done to safeguard the interests of the consumers? I should put down as the first duty of the water-works engineer or superintendent that of furnishing water that can be relied upon to their users. If you are expending a good deal of money to make a supply safe, you should see that it is safe at all times. Therefore you must see that polluted river water does not enter the pipes of your system outside of the mill, leaving out for the present all discussion of the use within the mill. I believe that this problem will work itself out within a few years, and new methods will be devised to prevent the possibility of this extra pressure forcing water by the check valve.

In talking with some of the representatives of the various industries in Springfield, I find that nearly all of them are heartily in

accord with the water board. They do not want to do anything which will endanger any of their employees or endanger the city.

Of the 62 Springfield industries that I studied, only 5 check against the city water at the present time with water from a polluted source, — Connecticut, Mill, or Chicopee rivers. The whole question is on those of that character. These 62, outside of the 5 which do check, including some of our largest industries, have developed their secondary supply for the sprinkler system and fire hose by means of tanks on the roof. The department can meet such cases at least half way. It can agree to furnish free all of the water which is to be used for fire protection, if the mills will eliminate their other supply, and this will in a large measure remove the objection on the ground of additional expense.

Another class of users are those who regularly use water from the river or nearby supply and have an auxiliary branch that can be drawn from the city mains. In such cases, for example, a certain large power plant, which does not use the city water unless the private supply is short or there is something wrong with the pump, double positive valves can be arranged with an open tap between, which under proper inspection, I believe, can be made to serve the purpose.

In one of the main cases which I studied, and one which bothered me most, on presenting the matter to the insurance companies, I was told that it simply came to a matter of putting in a separate tank, and a portion of the pipes separately, which would supply with the city water all of the sprinklers from the tank. I was assured by them that such an arrangement would make no difference in the rates.

In regard to the reasons for keeping out the outside water, I don't know that it is necessary to say much. The chief water-borne disease that we can find definite records of, and that we need to look out for, is typhoid. In one plant in Springfield, where there is a check-valve, I find that warnings have been posted that the water is not to be used, because this danger is recognized. In this same plant they have had one case of typhoid which they lay to this source.

There have been a number of specific cases where the check-

valves have failed to operate, and one of them was a recent case in Chicopee, where the check-valve failed to properly keep out the water from the river.

The insurance men have met us more than half way in every instance, and have been alive to the situation and willing to do what they could to better the conditions. I believe that they all will shortly come to our assistance in the elimination of the evils. The very fact that those industries which are located where they cannot get the city water have been taken care of by them, seems to me a fair argument that if they should want water regularly for fire protection they should have it in an independent system. Even though the development may be slow, it is sure to come.

The President. We had hoped to have Mr. Thomas with us to-day, to tell us something of the experience they have had with check-valves in the city of Lowell. As he is not here, perhaps Mr. Sullivan, of Nashua, who was in Lowell at the time, can tell us something about that experience.

Mr. William F. Sullivan.* Mr. President, I am afraid I shall make a poor substitute for Mr. Thomas. Probably many of the members of this Association are somewhat familiar with the circumstances at the time referred to. I am not going to be very specific about names or places, sufficient to say that the failure of a check-valve kept a number of people on the run for quite awhile.

The facts, in regard to the Lowell case, are that back in 1849 the Locks and Canals Company, which is a sort of parent corporation supplying water power, fire service, engineering, etc., to the larger corporations, constructed a reservoir to supply water to the mills. In 1871 the city of Lowell put in a municipal supply, the city's low service reservoir being about 50 feet lower than that of the Locks and Canals. About 1876 the city laid a large supply pipe practically parallel to and adjacent to that supplying the large corporations. Since 1876 the mills from time to time put in 17 connections with check-valves of different designs, 15, 12-inch and 2, 8-inch, I believe.

Matters went along smoothly until about 1903, when a fire occurred in one corporation. It happened on a Saturday night in the summer time, when many of the mill officials, familiar with

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

details, were on vacations. Things got a little bit confused. The yard hydrant service and sprinklers drew upon the corporation supply so much that their pressure dropped below the city pressure, thus letting in the city supply in large quantities through these different checks. The fire was extinguished, and an engineer in one of the mills started up a fire pump. The canals were drawn off, and it is said that the suction for this fire pump was in a small basin under one of the mills and within a few hundred feet of a sewer outlet. Again it was contended that after the fire was out the fire pumps could neither replenish the water in the corporation reservoir nor increase the pressure on the corporation lines. Investigation showed that one of the 12-inch checks failed to work properly, and that the pumpage had been going back through the check-valve for an uncertain period of time. I believe nobody dared to say, or wanted to say, how much water passed backwards through the faulty check. Of course just as soon as it was found out that the check did not operate properly, the gate was closed.

Whether from the result of that mishap or some other cause, the typhoid fever cases jumped from an average of less than 2 per week to 75 the third week after. The city authorities blew out the mains and had the State Board of Health investigate, and samples were taken at different parts of the city for chemical and bacteriological examination. Some months afterward a well-known old-time lawyer in the city, who claimed he was affected by drinking city water on the day following the fire, sued the city and the Locks and Canals jointly, and wanted a trial by jury. It is said that somebody else thought justice would be served by other means, and I believe it was actually said that some of the defendant's witnesses fled from the process server. Some jocosely remarked that they were fugitives from justice.

After a while, like "Jarndyce and Jarndyce," the case went before a master in chancery, and I understand there it reposes. A great array of legal, engineering, and expert talent have been talking on this check-valve ever since.

Some years after the entry of the case the plaintiff died, and his administrator took up the case, and is still prosecuting and waiting for a decision. Whether this man ever drank water and contracted any ailment at that time is up to the Court to say. Some of us

have our own opinions which it might not be right to express at this time, as it might appear to be prejudging the case. Nevertheless, the board of health records show at that time an increase from less than 2 to 75 cases of typhoid per week. I do not say these cases were caused by the water. I don't dare to! The case isn't settled yet.

It was somewhat customary, years ago, to connect secondary supplies with the primary supplies in such a way that the secondary supply could be pumped directly into that of the city or town. City and corporation officials believed that such a union was of mutual advantage. The corporations would get the benefit of the city supply and the city would get the benefit of the corporation supply and pumps, in case of a breakdown or shortage in the city's supply. That was before the time of water sanitation, filtration, and purification. Times and methods have changed and the method of by-passing a check-valve and having a sealed gate in the by-pass, of by-passing a gate with a check-valve, is a practice not commonly adopted now. Of course with the by-pass the personal element always is present, and the gate after operation might not be closed absolutely tight, and during a fire test there would be liability of a large or small stream of polluted water getting back into the city mains.

In Nashua, within a comparatively short time, there was a corporation which had a 12-inch fire pipe with a 12-inch check-valve. As is customary, the insurance inspectors came around at the regular interval for inspection. One of the things they do is to try out the yard hydrants, etc., with city water. As we do not charge them for it, it is a case of let them blow away.

The next step is to try the fire pump. On this occasion, we got a hurry-up call. They couldn't increase the pressure over the normal, which ordinarily they ought to increase by forty pounds. We shut the gates and blew off the mains adjacent to the mills. Casually we were informed there was some intestinal sickness, but we never saw or heard of it. The people who lived in proximity to the mills didn't know anything about the test or the cause of the sickness, if there was any. The insurance folks, the corporation, and ourselves were content with the old adage, "Least said, soonest mended." We cannot, nevertheless, shut our eyes to the

fact that such occurrences are a menace to city and town supplies. Inspection of this check-valve when the cover was taken off, showed that the flapper was locked up, being wedged with tubercles. This check had been in for over twenty years and had never been examined.

In another New Hampshire city there was an arrangement by which the corporation fire pumps could pump into the city mains. The mill agent is reported to have said that such an arrangement was at the request of the city authorities. They had a fire that lasted many hours, and the fire department officials opened or had opened the gate connecting the city with the corporation and requested the mill people to pump into the mains. This was all unknown to the superintendent of the water works. The inevitable result of such action was a large dose of polluted water, much sickness, and fear of a typhoid fever epidemic.

On the smaller connections to buildings, factories, and mills supplying water direct to boilers, what superintendent of water works has not found that the check-valves do not hold? Generally the result is loss of water in the boilers, twisted and distorted disks and pistons on the meters.

In Nashua we are trying to divorce primary and secondary supplies absolutely. We believe it to be an unholy alliance. We have divorced most of them except where the corporations and insurance people have met us halfway by compromising and putting in safety devices. I want to say right here that these insurance men are thoroughly trained and on to their jobs all the time, and when you run up against them, you run up against some of the brightest and smartest fellows in the business. Where we are unable to absolutely separate the supplies on account of real hardship and expense, we allow double check-valves. We say that the supplies must be separated. If an agreement is not reached by means of double checking, we cut off the supply.

After the failure of the check-valve at Lowell, the corporations increased their pipe capacity from their reservoir, and are now self-contained, as it were, and can take care of themselves inside the mill yards. The city of Lowell increased the number of hydrants outside the mill yards.

Whenever there is a chance of polluting a city supply, I believe

such changes are imperative. If corporations do not want to assume the entire responsibility of a fire supply, and are desirous of continuing a secondary supply in union with the city's, let them build tanks or reservoirs of ample size and capacity, and keep them filled with the water furnished to the inhabitants, the water works to adopt rules regarding drawing off, cleaning, etc. Let them take this reserve supply, fill up their tanks and run their fire pumps with city water, and not with polluted water.

As I have said, we have compromised and put in the double check system. In addition to double checking, we also want a check on the water passing through the fire pipes. Our method is to put on a straight commercial check, not the kind that sticks. Back of that, towards the inlet, we put on a Hersey detector meter. On the side and around the checks we have a testing apparatus so arranged that we can increase the pressure on either check and tell from the gages if any water is going back. The telltale meter on the detector informs us if the flapper is off its seat. If the water is going forward, it is up to the mill officials to look into the matter. If it is going backwards, it is time for the water works people to stop it. There is also an electrical connection to a bell which will ring in case of the failure of a check-valve. This was worked out in conjunction with the insurance people for these particular places, and no doubt could be employed under similar conditions elsewhere.

You probably heard Mr. Coggeshall, of New Bedford, tell about the salt water being pumped into his mains, causing the water in the fire engines boilers to foam. I am half inclined to believe, as Mr. Brooks once remarked, that check-valves were the invention of the devil! The members of this Association once visited a valve factory where they also manufactured check-valves, and there were some fine goods on exhibition. I went over to a 6-inch check-valve that had the cover off. It was soon after the Lowell affair, and I was curious, and desirous of learning something about check-valves. I pulled up the flapper and it stuck. I pushed it down again and pulled it up. Again it stuck. Several other gentlemen came over to where the check-valve was and looked it over carefully. I called the attention of the superintendent, who had recently taken charge. He saw at a glance that

there was something inherently wrong in the design and construction of that check-valve, and immediately ordered that particular exhibit to be shelved.

I have often wondered how many check-valves of that design were in use, and if every time water was forced through them in large quantities so that the flapper was raised to its full height, if it would stick.

Another grievance against check-valves has been that they have been put into the ground without a chamber or manhole, and quite often there is no record of their location. I have known cases where the mill people were uncertain whether there was a check on the line. In such cases it would have to be determined by testing, and it would be almost impossible, sometimes, for the so-called oldest employee in the mill to locate the valve.

Mr. E. C. Brooks.* I thoroughly agree with Mr. Sullivan. I would say that in Cambridge we get over the trouble from a double supply very nicely by having inserted in the regulations for fire supplies that no pipe on the premises shall be so arranged as to take water from any other source than from the Cambridge supply. They have a number of brick or concrete cisterns of ample capacity, — 100 000 gallons, for instance,— with a 6-inch line running into them, and the fire pump is connected directly with the cistern, drips of every kind being excluded. I think in that way you can safeguard the secondary supply very well.

In regard to check-valves, I would say that two are only twice as good as one, and if one isn't worth anything you can judge what two are worth.

In regard to positive valves, which Mr. Lochridge spoke of, I had occasion some time ago, in connection with Mr. Williams, the chief mechanical engineer of the Boston Elevated, to arrange a system of piping whereby they could supply their boilers at the power station either from Charles River, the water in which since the construction of the dam has lost enough of its salinity so that it can be used for boiler purposes, or from the city water. By designing a 3-way cock, giving sufficient space between the openings so it would be impossible to have the cock open on both supplies at the same time, it was easy to provide a means of

* Superintendent of Water Works, Cambridge, Mass.

accomplishing that end without any difficulty. I think that the secondary supply always has its dangers, and that we ought to be on the lookout against fire pumps taking anything in the way of polluted water which is liable to be forced back into the mains.

While I am talking about fire pumps, I would say that the fire insurance people have passed fire pumps as being in good condition when from the running of the pumps there has been a ram on the mains in the immediate vicinity sufficient to disturb the piping in the buildings of adjacent property owners, and that that could only come from imperfect suction valves; and that it isn't always safe to say that because a pump runs it is all right. Unless you have got a gage on the suction side of your pump that is sensitive enough to show the variation in pressure, I don't think you can judge really of the condition of the fire pump. I have had two cases recently where that has been the trouble.

Mr. John J. Kirkpatrick.* Mr. President, we have about 100 check-valves located on services that were put in for the purposes of providing fire protection to our mills and factories. With but two or three exceptions have we found fault with the operation of those check-valves. Those two or three exceptions, however, have convinced us that the operation of the check-valve is most successful when there is a gate valve behind it closed tight.

Last year, because of the changing of the grade at a railroad crossing, we had occasion to dig up a check-valve which was on the pipe line between the high-service section and the low-service section. We have a reservoir which supplies the higher elevations of the city that is called the High Service Reservoir, the lower elevations being supplied from other reservoirs. The check-valve was a small one, an 8-inch, and as we dug down to it we plainly heard the water passing through from the higher pressure to the lower pressure. When the check-valve was pulled out it was found to be so corroded and filled up with silt and rust that it would not close. That check-valve was not replaced, a gate valve being put there instead.

The check-valves that we have on the services for the mills are, of course, put in by the mill owners, all of whom use fire pumps.

* Superintendent of Water Works, Holyoke, Mass.

They pump water either from the Connecticut River or from the canal, the water in the canal coming from the river above the dam.

The insurance inspectors, when they are making their annual tests, are required by our board of water commissioners to first test the fire pump. They do this after closing the gate valve that is located between the check-valve and the street main. After the fire pump is tested the hydrants in the mill yard are opened to let out any river or canal water that may be in the sprinkler system at a higher elevation than that at which the hydrants are laid. This water will run out slowly, as the pressure seldom exceeds 12 or 15 pounds. After that operation the hydrants in the mill yard and the sprinkler outlets are opened, and the whole system is flushed out with city water.

The insurance companies have shown a disposition to comply with the rules of the water board, and up to date the inspectors have done everything they were requested to do while making their tests.

Mr. Ermon M. Peck.* Here in Hartford we have nine plants the pipes of which are fitted with double check-valves. There are altogether 13 of these double check devices in use here, one of the plants having 3, two others having 2 each, and six having 1 each. I want to pay a just tribute to the insurance men and to the manufacturers for the manner in which the placing of those valves in our city was effected. The matter was adjusted most harmoniously, all parties working together with the very best will and intention towards the water department, and the consequence was the whole thing passed through with absolutely no friction whatever. There was some delay in getting the devices installed. In some places the construction was very expensive, and there was some delay in getting the necessary fittings and appliances; but otherwise everything went very nicely.

The conditions here in Hartford, in some respects, are unusual. We have to our credit the statement of the local board of health that no case of typhoid fever has ever been directly traced to our water supply. But the fact that Hartford has had no typhoid fever epidemic is no proof whatever that it may not have one, because they do occur in other places. During the time that we

* Distribution Engineer, Hartford Water Works, Connecticut.

were installing these new check-valves, an old type of check-valve was taken out, which gave evidence of having leaked considerably; it was one which had been used between the polluted supply of the Park River and our regular city supply.

We have established the custom here in Hartford of testing the valves monthly. We have an engineer who goes around and tests each one of them every month, and the manufacturers very gladly bear the expense of it.

I thought that just a word regarding the check that we use here would be interesting. We use a special check, one which was settled upon between the water department and the insurance men, and it was made by the Pratt & Cady Company. I am very glad that Mr. Robert Shirley, the former engineer of the Pratt & Cady Company, is here this afternoon. I think he will be glad to say a few words regarding the construction and design of this check, and I believe you will be interested in listening to him.

Mr. Robert Shirley.* This check-valve, as Mr. Peck has said, had to be satisfactory to the insurance people and to Mr. Peck himself. We had found from experience that a properly made rubber disk had good lasting qualities, as we had taken samples of disks from different valves which had been in use for fifteen years, and they were in good condition. So we decided to make the disk of rubber. It is very seldom you can find a standard check tight — by standard, I mean a regular commercial check bought in the open market. It is almost a physical impossibility to make and keep it tight under low pressure, and these valves generally work under low pressure as far as the disk is concerned. For instance, if the city pressure is 80 pounds, and the pumps maintain 90 pounds, the pressure holding the disk to its seat would be 10 pounds. It is important, therefore, that the check should be tight when tested, with practically no pressure against the disk.

As you all know, it is the pressure against the disk which holds the disk to the seat; consequently, if you get a scratch on the brass face of your disk, your check is no longer tight. We found that under 50 pounds pressure, with a rubber disk bringing up against a flat brass seat, the check would leak, the rubber having

* Works Manager, Chapman Valve Manufacturing Company, Indian Orchard, Mass.

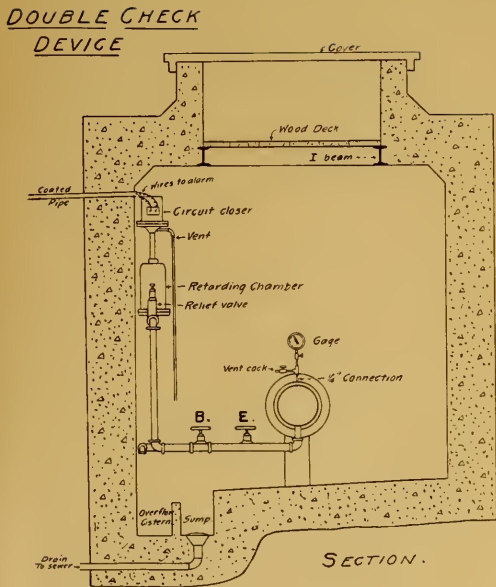


FIG. 1. CROSS SECTION.

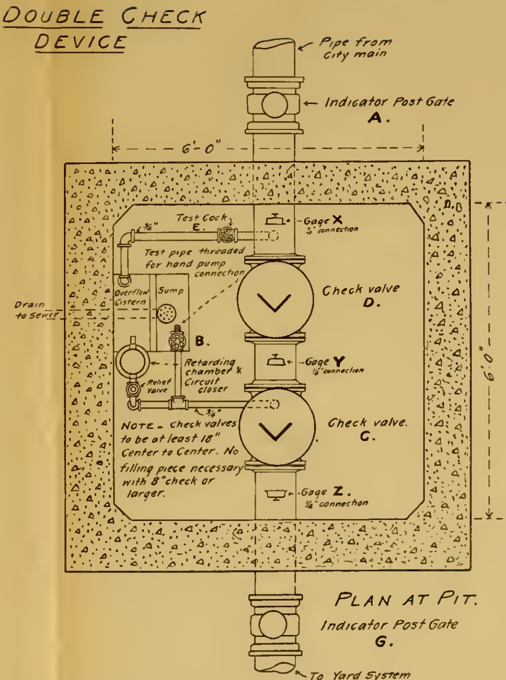


FIG. 2. PLAN.

DOUBLE CHECK DEVICE AS USED BY THE HARTFORD WATER WORKS.

little unevennesses on the face, but by turning the rubber off, we thought we could make it tight, yet it still leaked quite a little on low pressures. We then went to work and rounded the face of the brass seat of the check, and that allowed it to crowd into the rubber more, giving a perfect seat, so that at pressures under 10 pounds the check was tight. The check was made with a large clearance around the disk, and the side plugs which support the arm or the hinge, as some manufacturers call it, was made to

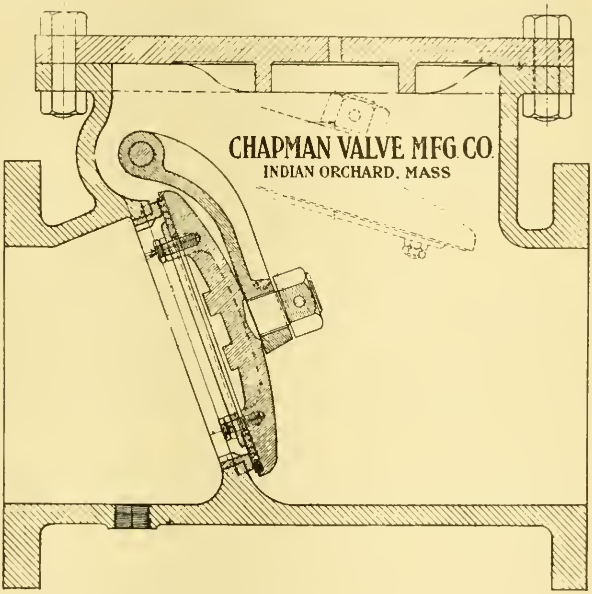


Fig. 1.
Recent Design for a Check Valve, approved by the Fire Underwriters.

project into the check at least 0.25 in. beyond the iron, so that there was no chance for tubercles to form, or for corrosion to effect the working of the disk. The arm was made of solid bronze instead of the malleable iron or wrought iron or steel arm in general use in standard commercial checks. The disk itself was made of iron, with a cast-iron plate holding the rubber disk in place. It was found on examining the checks in some localities

that corrosion had taken place, and all over the rubber seat there were deposits of rust, which were liable to cause the check to leak. The design was then changed, so that the disk is now made of solid bronze, and the holding plate is also bronze, so that, as now built, all the inside working parts are bronze, and the danger from corrosion is eliminated.

Fig. 1 shows a recent design of a check-valve, approved by the fire underwriters.

Mr. George A. Stacy.* I do not think our conditions in Marlboro would exactly cover this subject in the form of danger from pollution.

We have quite a number of check-valves, under pressure from 15 or 20 pounds up to 180. In our city we depend upon hydrant pressure entirely for our fire service. The city is rather uneven. The distributing reservoir is virtually in the city, and on the distributing mains for domestic supply the pressure varies from 14 pounds to 142. In the higher levels of the city, where some of the largest factories and buildings are, we have only 30 pounds. In passing from the old hand-engine protection to water works, we abandoned the use of engines entirely. About 1894 the insurance people, on account of the growth of the factories and the increase in the size of the buildings in other parts of this district, demanded either a higher pressure or steamers. The matter was taken up by the chief engineer and myself, and we submitted it to a committee appointed by the city, and it was decided to put in a standpipe with three miles of independent mains to cover this district. Previous to the introduction of the standpipe we had introduced in every factory two sources of supply from different sections of the pipe line, so that if one section broke we could cut it off and still have a supply for the factory. When the high service, as we call it, was introduced, they requested that it should be connected with the sprinkler systems in that district, and here was a problem for us to meet. They wanted both supplies on at the same time, the one with 85 pounds pressure and the other with 30. In doing this we put a check-valve on the low-pressure supply in a manhole outside the factory (with an arrangement to test the check). The idea was to have them automatic, so if the high service was shut

* Superintendent of Water Works, Marlboro, Mass.

off the low service would supply the factory. That was introduced in 1896.

The distributing reservoir is on Mount Sligo, and immediately at the south end of the reservoir is the standpipe on a trestle 75 feet high. The two distributing mains leave the reservoir grounds within 20 feet of each other, and at that point there is a cross-over pipe connecting the two together, for the reason that we wanted these three miles of main to be available for fire protection (by being supplied from the reservoir), supposing anything should happen to the standpipe, or that the pump should fail. I will say there is a pump there of a million and a half gallons connected with this high service, pumping directly to the standpipe and its distributing mains. In that cross-over pipe was a check with a gate valve on each side. In all our experience we haven't found a leaky check-valve yet, although they have been tested many times. The inspectors shut off the high service, and then the low service, so the check-valves are open more or less.

When we clean and paint the standpipe we shut the valve at the bottom of the standpipe, after emptying it, then if we have a fire, the fire pump or reservoir supplies what water is used, and the check-valve or the cross-over pipe is opened and closed more or less.

In the factories, from the closest tests we have made of them, we haven't found a leaky check-valve up to the present time. These check-valves are of metal, seats and valves scraped in, made to special order. We have on the Worthington pump force main under 180 pounds pressure, a 16-inch check-valve, with four leaves in the valve, and that is absolutely tight. I have one check on the force main of the Blake engine that has leather faced valves, that has proved to be tight; but it has had to be renewed a number of times.

We haven't got at stake what the other people have, where the pumps are connected with polluted supplies; and notwithstanding the success that we have had with check-valves, if it were possible that a polluted supply of water was on the other side of a check-valve, I don't think I should feel very easy about it, even with all my experience, with the present type of valve, which I believe is the best that can be made, for clear water. I know very well it

wouldn't take but a very little to make one of these valves leak. But so far we have been very fortunate in the matter.

In listening to the experience of others, and from what I know of the mechanical construction of valves, and from what I have learned from my experience and work in that direction, I think it resolves itself pretty near to this: So far as check-valves are concerned in protecting your water supply from pollution, where there is a polluted supply on the other side, it is a good deal like the answer that was given in this Association a good many years ago by an old water-works superintendent, who had been all his life in the business and had a vast experience. We had been discussing how to keep water pipes from freezing in the winter, and we had heard all sorts of experiences, and at last we asked him for his experience, and what he thought was the best method to keep water pipes from freezing. That was during a time when we had been having some very severe cold weather. He said, "In my experience I have tried a good many things, all I could hear of and all I could think of, and I don't know of but two methods, — either put them below the frost, or keep the water out of them."

Mr. Edward V. French.* *Mr. President and Gentlemen,* — When I met the president this noon, he suggested that somebody was wanted to speak for the other side, and as he knew I was used to taking that position he said he would like to hear from me to-day, this being in line with a little previous warning. I think I have quite a task before me to bring out the other side of this question. I got a little anxious while Mr. Sullivan was talking, in spite of the kind remarks he made. It seems to me he has put the thing on the right basis when he tells us that this is a question of divorce. I think the "divorce evil" has gone on to a pretty serious extent already, and it may be that in this matter we ought to take some steps to check it.

There are two sides to most any question, and it is desirable, as the president said when he asked me to take a little interest in this, to have both sides brought out. We may well consider that there are two functions, at least, of a public water supply, and I agree, as Mr. Lochridge has stated, that the most important one is the furnishing of pure water. But there are other functions,

* Vice-President and Engineer, Arkwright Mutual Fire Insurance Company.

and I think nobody here will disagree when I say that an important function is the extinguishing of fire. It is for that reason that water systems are arranged with high pressures, following in the best practice what Springfield has recently done, and furnishing pressures that will give excellent fire streams all over the city. Large mains are then provided so we not only get good pressure but the pressure can be maintained with a large draft of water. Now, there is no use in doing this and then cutting off the largest benefit that can be obtained from fire service, if there is any reasonable way of avoiding it. It is on that side that I should like to speak for a little and attempt to bring out a few points.

I think there is no one of us who would not feel that the arrangement of fire services must be made so that the danger of polluting the drinking water supply is practically eliminated. In taking the matter up in a good many cases with the mills having such protection, they have all, in every case, agreed that as good citizens that was their first duty. The fact that conditions which have been so well described to-day exist in some places is easily explained. It is not a great many years ago when the city of Lowell, as Mr. Sullivan told us, was taking its water supply from that same river, and there was then little impropriety in having the fire pumps draw from the same water which the city was taking. Our changing views as to the need of pure water, which have been quite recent, comparatively, have brought about the criticising of these older arrangements, which have not been changed, perhaps, as rapidly as our ideas as to the need of pure water have changed. So we may consider, first, whether there is not some easy and reasonable means of overcoming this danger, in a way that will practically eliminate it.

We may first consider, then, what the danger really is. The ordinary fire system supplies automatic sprinklers and private hydrants, and the public water is connected to it, maintaining pressure on all this apparatus all the time. The automatic sprinkler system, in order to do its work, must have a good pressure on it, with pipes of such size that, when the sprinklers open, every sprinkler that opens, be it two sprinklers or fifty, will get an ample supply of water. Then a secondary supply is usually necessary for two reasons: the first, to give *additional* water when a large

fire occurs. A supply from the public mains with, say, 700 to 1 000 gallons a minute, delivered at good pressure, is a very good *primary* water supply for average conditions: but if a large mill gets well on fire, this is not at all enough water to cope with such a fire, and then an additional supply must come in. When a fire opens a great many sprinklers, it is necessary to put the additional water into those sprinklers and not depend exclusively on fire streams for fighting the fire. In order to do that, fire pumps are usually provided, taking water from some available source and discharging into the sprinklers and private hydrants, and supplementing the public supply, so that the sum of the waters available from the public source and the private pumps is ample to cope with any fire likely to occur.

In a great many places the public supply cannot give water enough. Mr. Lochridge has cited Springfield, and Springfield, perhaps, has almost the best — possibly the best — water supply for a city of its size in this country, not only in its quality, but in pressure and capacity; and the conditions there are ideal. They never can be reached in many of our cities. So that while in Springfield the secondary supply required may be much less in quantity than in other places, it is nevertheless likely to be needed and this does not relieve us in the other places from the necessity of a large and liberal secondary supply. It has in a number of cases, with public supplies of ordinary capacity, happened that steam fire engines and hose streams drawing from the town or city water have drawn down the pressure in the street mains so that there was little or no water available for automatic sprinklers. In such cases there is need of a good secondary supply inside of the yard check-valves for the automatic sprinklers.

The second reason for our secondary water supply is for duplication of service, — not only to get more water but to get two strings to our bow, so to speak, so if one source of water supply fails the other one will be available. As our water-works systems improve, as our public systems are strengthened, the chances of breakdowns become less; but, as Mr. Lochridge has intimated, it was only a few months ago that Springfield, just before its new supply was turned on, was practically without water for two or three days in some sections. That is a condition which is not

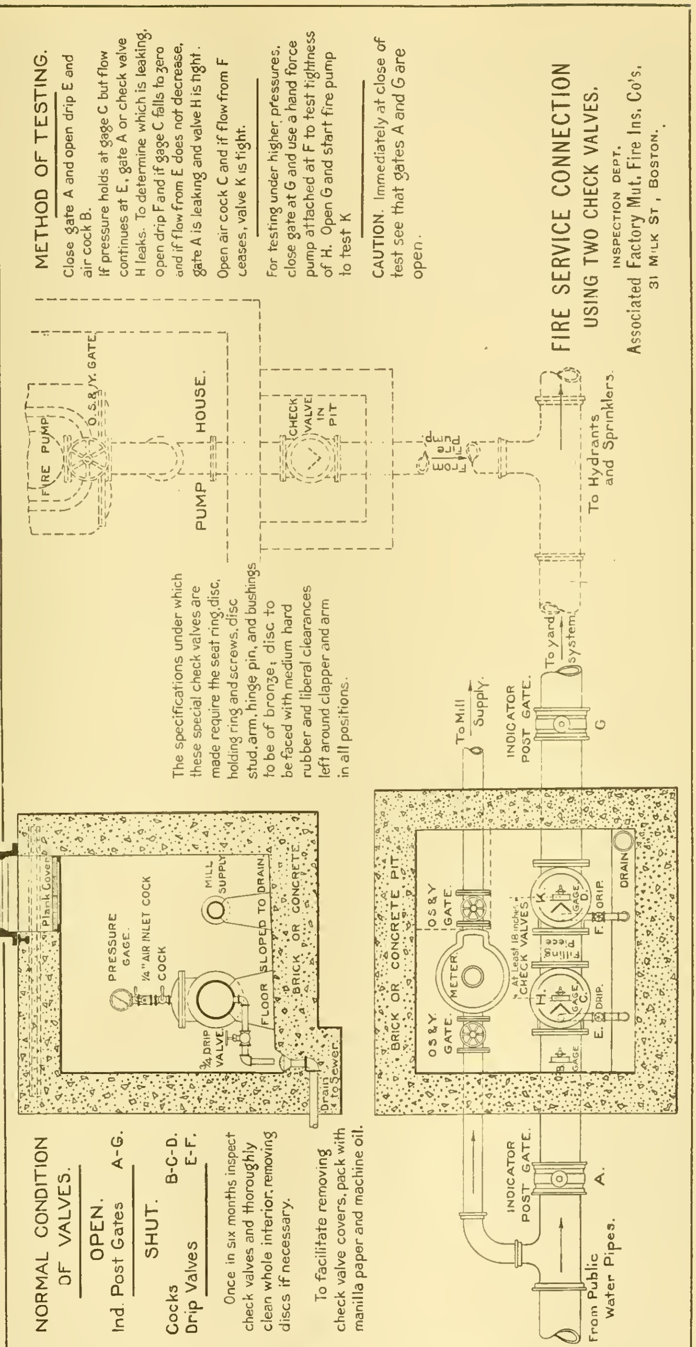

METHOD OF TESTING.
Close gate A and open drip E and air cock B.
If pressure holds at gage C but flow continues at E, gate A or check valve H leaks. To determine which is leaking, open drip F and if gage C falls to zero and if flow from E does not decrease, gate A is leaking and valve H is tight.
Open air cock C and if flow from F ceases, valve K is tight.
For testing under higher pressures, close gate at G and use a hand force pump attached at F to test tightness of H. Open G and start fire pump to test K
CAUTION. Immediately at close of test see that gates A and G are open.
FIRE SERVICE CONNECTION
USING TWO CHECK VALVES.
INSPECTION DEPT.
Associated Factory Mut. Fire Ins. Co's,
31 MILK ST, BOSTON.
NORMAL CONDITION OF VALVES.
OPEN.
Ind. Post Gates A-G.
SHUT.
Cocks B-C-D.
Drip Valves E-F.
Once in six months inspect check valves and thoroughly clean whole interior, removing discs if necessary.
To facilitate removing check valve covers, pack with manilla paper and machine oil.
The specifications under which these special check valves are made require the seat ring, disc, holding ring and screws, disc stud, arm, hinge pin, and bushings to be of bronze; disc to be faced with medium hard rubber and liberal clearances left around clapper and arm in all positions.
FIRE PUMP
O.S.&Y. GATE
PUMP HOUSE.
CHECK VALVE IN PIT
From Fire Pump
To Hydrants and Sprinklers.
To yard system
To Mill Supply.
INDICATOR POST GATE.
G
INDICATOR POST GATE.
A.
From Public Water Pipes.
Plank Cover
PRESSURE GAGE.
1/4" AIR INLET COCK
MILL SUPPLY
3/4 DRIP VALVE
FLOOR SLOPED TO DRAIN
BRICK OR CONCRETE
Drain to Sewer.
BRICK OR CONCRETE PIT.
OS&Y. GATE.
METER
At Least 18 inches CHECK VALVES
Filling Piece
H.
K.
GAGE C.
GAGE D.
B GAGE
E. DRIP.
F. DRIP.
DRAIN

FIG. 2.

likely to occur again in Springfield, probably never will, but it is a condition which may occur in some other city, and at such a time should a fire break out, our secondary water supplies are our only salvation, — the sole reliance to prevent a most serious loss from fire.

Then, again, there are the ordinary breaks, and occasional shutdowns for changes, making it, where very large risks are to be protected, and where the success and prosperity of the communities depend on these industries, necessary to have ample secondary supplies. So that while, in a few places like Springfield, the public water is likely to be ample for almost any need, those places are the great exceptions, and even in Springfield moderate secondary supplies will generally be provided for factories.

Now, as to what the dangers are in these cases. In the first place, in the well-arranged private system, the water would enter the yard through one or two connections, seldom more, to-day. Those connections can be provided, as has been suggested to-day, with double check-valves. Such check-valves are put in wells, and the plan is to have them frequently and carefully inspected. The older check-valves were usually buried in the ground, and, as has been stated, their location was sometimes forgotten. But it is not necessary, with our modern equipments, that they should be so placed. Check-valves can be put where they are accessible and they can be inspected and looked after and tested just as carefully as any other part of the apparatus is tested. And it is the intention of the underwriters to include the testing of such check-valves as a part of their regular inspection service, giving them just as careful supervision as the sprinkler valves, or the pump, or any other important part of the fire equipment. This can be supplemented by such supervision by the water department as Mr. Peck has explained.

The arrangement of these valves is shown in Fig. 2. They are placed 18 in. apart on centers and are located in a pit. The necessary drips and gages are provided to permit testing each valve separately for tightness as described in the notes. Several manufacturers are prepared to supply the special check-valves for use with this arrangement.

Ordinarily, and always preferably, the fire system is used for no other purpose than to fight fires, and the fire pump in a majority of factories is only run in case of fire and for occasional testing. So that, the only time when there is pressure against the check-valve is either during a fire, when the fire pump is running, or during the occasional tests.

The testing work can be arranged, as has also been outlined at Holyoke, by first testing the pump, closing the valve on the city connection before the test commences; then open the valve and test the hydrants and blow out any river water that has been forced into the system by the fire pump. Then the inspector makes sure that he leaves the valves open, and the chance of trouble is practically nothing. It can also be arranged, where necessary and proper, to keep the discharge valve on the fire pump itself closed, and sealed, with the understanding that the breaking of the seal must be explained to the water department, the seal to be broken only in case of fire or by permission from the water department.

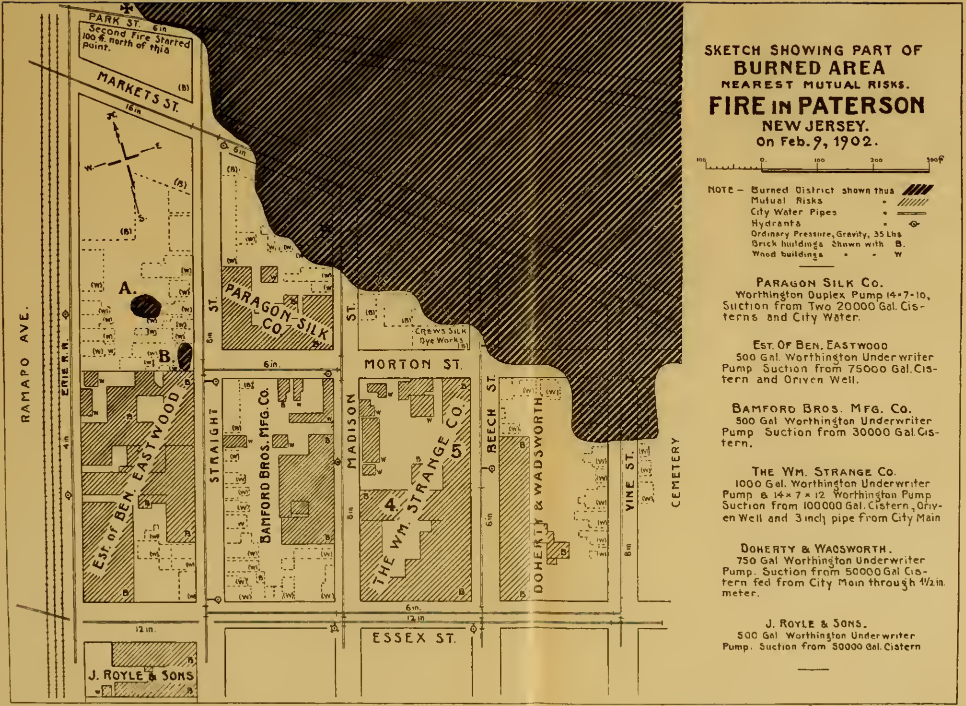
In all these ways we bring it to about this: That the only time, practically, that the check-valve in the service from the city needs to be subject to pressure against it higher than the city pressure, and, therefore, the only time when the public water is at all subjected to danger of pollution should the check leak, is the time of fire. In a protected manufacturing plant or mercantile building, fires requiring the use of the pump are infrequent, and if, therefore, we reduce the periods when that danger can exist to a very small number, and if, then, we guard those periods by a carefully arranged system of two check-valves, made as has been described, inspected as I have stated, we reduce the chance of trouble to an extremely small point. With reasonable supervision, and with good coöperation between the fire protection engineer and the water-works man, the possibility of trouble is reduced to a much smaller point than many other chances of pollution existing in the average water-works system.

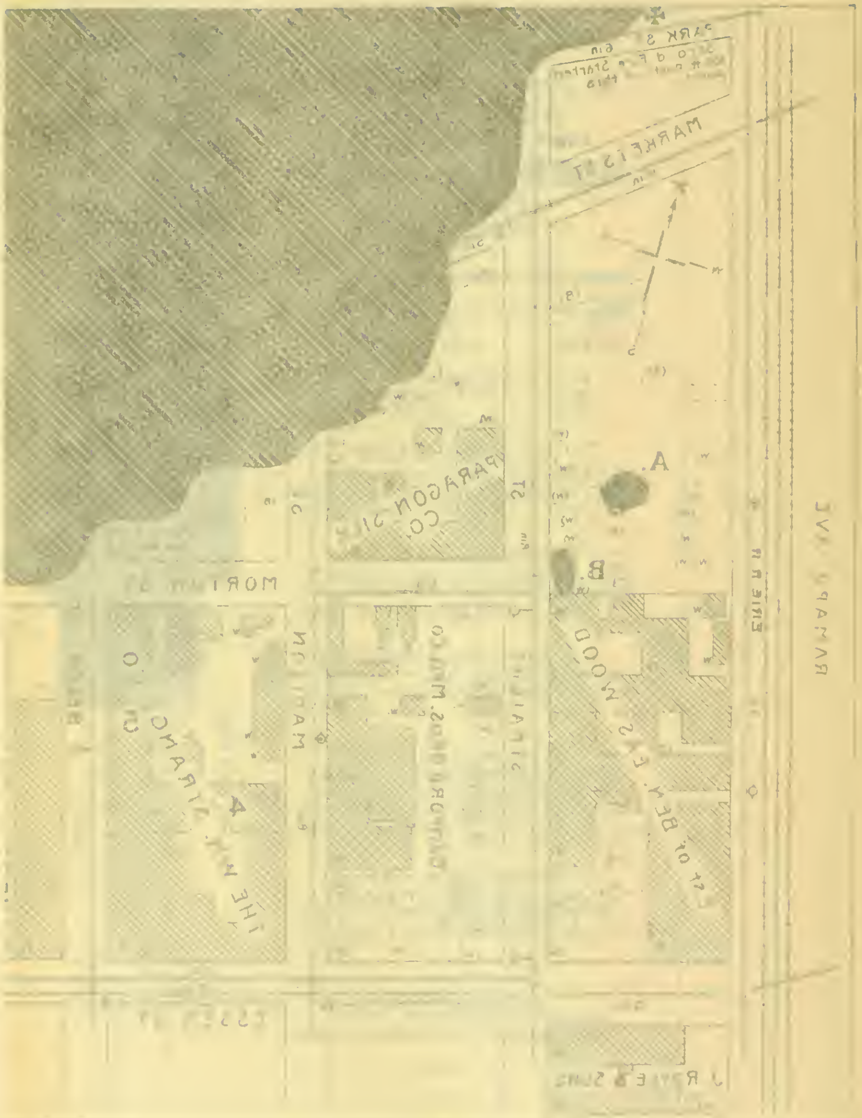
We are very apt, all of us, in looking over this problem, to over-estimate the danger, and because these cases from the past, with arrangements that are not up to date and do not represent the best practice, have here and there given trouble, to condemn

the whole thing. But this is the other side, which, as I say, it is my mission to try to bring to you.

Now, a word as to the value of these supplies. It may be brought up that the secondary supply is not often needed. But take the case of the conflagration at Paterson, N. J., some years ago. The city had a very good water supply and very fair pressure. The fire came down toward half a dozen silk mills. This was the second fire, Paterson having practically two fires, one starting from the other. The public fire department had exhausted about all its energies, and when the fire approached these silk mills there was only one steamer available for a long line of defense. The mills got out their fire streams, started their pumps, taking water from their cisterns, supplemented by what water might flow in from the public mains, and fought the fire as it came towards them, wetting down the houses that were burning, putting out the fires on the roofs from sparks, which deluged the mills like a summer shower, and when the fire was over a map of Paterson (Plate II) showed a long line where the black destruction stopped right parallel with those mills and nearly up to them. That is, those mills stopped that fire. They not only saved themselves, but they saved a large section of Paterson beyond. Now there was a case in a city where the secondary water supply saved millions of dollars.

Take another fire. The Cocheco Mill at Dover, N. H., burned. The public water there was of very good pressure and quantity. The mill was a large one. The weather was extremely cold. The fire started in the early morning and got away, due to the fact that the sprinklers were shut off at the time for some repairs, and it became a long fight. Fire pumps were started, three or four of them, and help was called from outside. The fire was finally extinguished and a large part of the mill buildings were saved. We made in that case a careful estimate of the amount of water used and found the total amount of water from Saturday morning, when the fire started, until Monday afternoon, when it was out, discharged on to the fire was about 8 000 000 gallons. Part of it came from the city, but the larger part from the factory fire pumps. Had the pumps taken their water from a limited source, the water supply would have failed absolutely before the fire was under


SKETCH SHOWING PART OF
BURNED AREA
NEAREST MUTUAL RISKS.
FIRE IN PATERSON
NEW JERSEY.
On Feb. 9, 1902.
NOTE – Burned District shown thus
Mutual Risks
City Water Pipes
Hydrants
Ordinary Pressure, Gravity, 35 Lbs
Brick buildings shown with B.
Wood buildings - - W
PARAGON SILK CO.
Worthington Duplex Pump 14×7×10, Suction from Two 20000 Gal. Cisterns and City Water.
EST. OF BEN. EASTWOOD
500 Gal. Worthington Underwriter Pump Suction from 75000 Gal. Cistern and Driven Well.
BAMFORD BROS. MFG. CO.
500 Gal Worthington Underwriter Pump Suction from 30000 Gal. Cistern.
THE WM. STRANGE CO.
1000 Gal. Worthington Underwriter Pump & 14×7×12 Worthington Pump Suction from 100000 Gal. Cistern, Driven Well and 3 inch pipe from City Main
DOHERTY & WADSWORTH.
750 Gal Worthington Underwriter Pump. Suction from 50000 Gal Cistern fed from City Main through 1½ in. meter.
J. ROYLE & SONS.
500 Gal Worthington Underwriter Pump. Suction from 50000 Gal. Cistern
PARK ST.
Second Fire Started 100 ft. north of this point.
MARKETS ST.
RAMAPO AVE.
ERIE R.R.
A.
B.
EST. OF BEN. EASTWOOD
STRAIGHT ST.
PARAGON SILK CO.
BAMFORD BROS. MFG. CO.
MADISON ST.
MORTON ST.
CREWS SILK Dye Works
THE WM. STRANGE CO.
4
5
BEECH ST.
DOHERTY & WADSWORTH
VINE ST.
CEMETERY
ESSEX ST.
J. ROYLE & SONS


MARKET ST
MORTON ST
PARAGON SILK CO.
RAMAPO AVE
ERIE R.R.
A.
B.
J. RYLE & SONS

control, and the mill would probably have been totally destroyed. So there was another actual case where the secondary supply saved the day.

There are many other cases of a similar kind, but two or three are just as good as more. The secondary supply, like any other reserve, does not come into use very often, but it is a thing that, when you do need it, like the Kentucky man's pistol, you need it mighty bad, and if you don't have it great destruction may result.

You cannot get at present in most cases any other supply for fire pumps as liberal as the ponds and rivers from which these pumps frequently draw. You can build a cistern holding an hour's or two hours' or three hours' supply, but that will not take the place of the unlimited supply from a pond or a river. So that the minute the practice comes to this, that it is absolutely necessary to forbid the drawing of such waters through fire pumps, under any sort of restrictions, just that minute your protection is reduced in efficiency, and in many cases very materially reduced; and, further than that, the cost is very largely increased. A plant worth five hundred thousand or a million dollars, or even a larger amount, cannot afford to take chances of having its business taken away or even seriously interrupted by fire due to inefficient or inadequate protection.

Now, we have on the one hand the practical question of fire protection engineering; we have on the other hand the health question; the two need not conflict. Isn't it possible that the very largest use of our public water systems, and the greatest benefit from them, can be secured by putting our energies into the perfecting of the double-check method as it stands, or of developing even better apparatus? Is it not possible that the water-supply engineer can thus find a way to still make his water supply of the greatest value for fire protection, while fully protecting it by insisting on the most complete and efficient but not prohibitive safeguards? If that can be done, it means that we retain the broad benefits which come from public water supplies of good pressure and large capacity. If it cannot be done, if we are not willing to look at that side of it, but take the easier method of cutting off the water supply entirely, without having patience to study it, then we cut off from our water-supply systems a very large function and

a very valuable work which they are capable of doing. It is to be hoped that our ingenuity and our patience and our desire to look at this problem broadly will enable us to work out these safeguards together until we can combine the two main functions of water supplies in a safe and reasonable way. And it is upon that side of it, knowing that what has been done looks very satisfactory and promising, as Mr. Peck has stated to us, that I want to appeal for the broader view of this problem. We should not throw away all these possibilities; any one can say that absolute separation is certainly safe, but we ought to use our full energies and all the power of our minds and our ingenuity to perfect these safeguards which in very many cases, at least for many years to come, can reduce this danger to a point that is negligible.

Mr. Lochridge. I want to take issue with some statements that Mr. French has made, and to say that I agree with him in some of the others. I believe thoroughly in the protection of the mill or of any property. I believe that the function of a water supply is, first, the furnishing of a pure water to all the people all the time; and, second, and just inferior to the first, the furnishing of an adequate fire supply.

Springfield isn't different from other cities, except that we have our supply substantially completed. If you go through the list of cities represented here, they are all on the up grade, they are all striving for a supply which will give very much more efficient fire service. To-day we are laying mains — and as a rule all the cities are laying larger mains — not sufficient simply to secure drinking water, but to secure adequate fire protection.

If we must have the second supply, what we want is something that is safe. I am willing to grant that the double-check system is a great improvement, and I am willing to grant that in many cases it may be practically safe. *Practically* safe is a good stepping stone. In the study of a great many fire risks that are controlled by the various insurance companies, you will find that many of them could be taken care of by an independent system at a small cost. I have run over the cost of separating these systems and carrying the water directly to the tank or to the sprinklers, and also to the hydrants, and I have found out what it would be. We must remember that in most cases, and especially with us,

nothing whatever is charged for the water. By this additional system large reductions in insurance rates are secured above what can be secured by a single system. Now, doesn't it seem to follow that it would be reasonable in a great many cases to have that system an absolutely independent system, have it thoroughly equipped, thoroughly inspected, always ready, and have it in such a way that the additional cost is put where it belongs, on that particular risk which secures the benefit of the lower rates? I am not in any way depreciating the value of the double-check system, but it seems to me that insurance men in general will put in a check-valve because it is a simple thing, because it is the quickest way to get at it. A great many risks are not large enough for a separate pipe system from independent sources, and a capacity sufficient for three or five or a dozen hydrants in the yard would be prohibitive. Yet such an arrangement would add an additional safety in the many cases where it is possible by providing a second complete system directly within their own walls and directly within their own property. In a number of the cases I studied, I found that the piping could be so carried that it could handle all of the sprinklers, with independent hydrants in the yard, where the city water could also be used, and in that way, while it might not carry all of them, it might be a great help.

I feel that the risks should make the departments recognize their responsibility, and meet them in such a way that, where it is possible to do such a thing, it can be done. It is not always necessary to change the whole system inside the mill. When you duplicate it, it does not mean that all the pipes must be duplicated. The sprinkler system can have a single pipe and have it furnished in the same way, and the secondary furnished from a tank, as in over fifty out of our sixty risks in Springfield.

In the cities where the lower pressure obtains, you should have your check even more absolute, because every time the pressure is raised you have the added danger of leaking in the check, or whatever the device is, which we would not have with the higher pressure.

I want to tell a little incident that happened on our system. We were greatly impressed with the insurance men's argument that the thing to do was to have some one ready to be the first

man on the spot when a fire starts; and in one of our largest establishments that is supplied with a check we put in a second check and a positive valve. One man, who was always on duty, was to have as his first duty, in case of fire, the closing of that valve against our system. After the first fire one of the engineers went out from our office, and he said, " Did you shut the valve as agreed? " "O, Lord! I never thought of it."

Mr. Sullivan. I have been interested in the remarks of Mr. French and of Mr. Lochridge. There was one point Mr. French brought out. That was, Fire Service *versus* Sanitation. I want to say a few words on the hazard of inspecting and testing fire services. The mills usually supply drinking water to the operatives from the fire pipes, such water at most times being city water. The inspectors have the fire pumps started, and pump water from the secondary supply into the fire pipes, generally during working hours. Such supply, in most cases, is a polluted supply. The employees of the mills and factories, if they want a drink while the testing is going on, or before the water is drawn off in the manner described by Mr. Kirkpatrick, get a chance to drink contaminated water. And I know that, in one place where I have been, the typhoid féver cases reported were tabulated and charted, and it was found that a very large percentage of the cases were found to be operatives who had access to the so-called canal water during working hours. We were almost certain that the city supply was safe, and it was certain that the operatives had not arrived at the delightful stage of civilization when they could go abroad or on vacations and contract typhoid at any of the watering places, and one of the conclusions we arrived at was, that when fire pumps were tested, the operatives got a dose of polluted water. Operatives drank the water in preference to waiting until it cleared up, as the custom was not to draw off the polluted water supply. In fact, many operatives knew nothing about the testing, or, in many cases, would not realize the danger if they did.

There have been, in most cases, absolutely no precautions taken to prevent operatives drinking the water during and following a fire test. I would like to ask Mr. Kirkpatrick what is done in case of fire at night-time; is the positive acting gate closed?

Mr. Kirkpatrick. Mr. President, it is — providéd the hydrant

man gets there before they turn the pump on. We have a hydrant man who answers every fire alarm, and if he happens to get there before the fire department, he closes the gate valve, providing the pump is in operation; otherwise he does not.

With regard to the other point Mr. Sullivan made, I think such cases as he has spoken of might be obviated by compelling the mills and factories to have independent services for drinking purposes only. There was a time in the city of Holyoke when mill operatives were allowed to use the canal water, for the pipes were all connected, as Mr. Sullivan stated. The local board of health and the water commissioners have ordered that practice abandoned, and the mills now have separate services to supply them with drinking water from the city mains.

Mr. M. F. Collins.* Check-valves do not seem to have any friends here this afternoon, so I guess a little more knocking won't do them any particular harm. In one of our mills in Lawrence in 1904 we had an epidemic of typhoid fever. We went to work and traced it out and found in the neighborhood of 36 or 40 cases in that one mill. The epidemic became so serious that we called the attention of the State Board of Health to it, and they had one of their employees at our local experimental station make a test of the water. He tested the water right around the check-valve which was there, and found the condition of the water was just about the same as it was in the Merrimac River before being filtered. The city of Lawrence has gone to the expense of purifying its water in order to give the people a pure water to drink. So, after finding out what the trouble was, we called the attention of the agent of the mill to it and asked him to put in an extra check-valve, which he did, and since that time we have had no trouble at all.

It is my opinion that check-valves as a rule are very uncertain quantities and not to be relied upon at any time, as far as being absolutely tight is concerned. There are two or three ways of looking at the check-valve. Mr. French says the only danger that he apprehended was when the fire pumps were being tested. In our mills the fire pumps are going twenty-four hours every day; they are not shut down at all. In the neighborhood of one of our mills, where there was a check-valve, we had considerable trouble

* Superintendent of Water Works, Lawrence, Mass.

and complaint about rusty water at one time. I saw the managers of the mill and they told me they didn't use any of our city water. I had a recording gage put in my office, and every time there was a complaint from that neighborhood I looked at my gage and I would find that there was quite a quantity of water being used, lowering the pressure on the gage. One morning I got a complaint of rusty water, and looking at the gage I found the pressure had lowered. It was then about eight o'clock. I drove right up to the mill and called out the master mechanic and asked him if they had been using our city water. He said no. I told him to go inside and find out whether they had or not, for I was sure they had, so he went in, saw the man who operated the fire pumps, and found that something had happened to the pump, and it had been shut down, he said, for between ten and fifteen minutes. The minute that pump shut down, — they have a pressure there right along of about 90 to 100 pounds against 65 on our mains,— our water ran into the mains in the mill; consequently, when they started up their pump there was a chance that some of that water would get into our mains. So I think that if the underwriters would get together and devise some means by which both systems could be separated, it would be a good thing.

Prof. Edward W. Bemis.* In Cleveland last year I began to take up this subject, and found such a condition as Mr. Collins has described, where the pressure from the fire pumps, that were running a great deal of the time, was very much greater than the pressure on our mains, and apparently there was no reliance to be placed on the check-valves. Finally an arrangement was entered into, and the Board of Public Services approved of it, for the absolute separation of the supplies, so that the pipes carrying our water would not carry any polluted water. They can have as many supplies in a factory as they wish, but there must be no connection between the two piping systems. That requirement is now gradually being put into effect, I understand, in Cleveland, and unless there can be a more efficient invention for a check-valve than seems to be yet before us, — something not yet apparently on the market, — I believe the time is coming when that requirement will be the universal practice. It is possible, as

* Deputy Water Commissioner, Water Supply, Gas, and Electricity, New York City.

Mr. Lochridge says, or it may be possible, to allow some of the piping, some of the sprinkler system, to be connected with both supplies, but most of the systems will have to be separated. I noticed in the two illustrations that Mr. French gave of the very great importance of the secondary supplies, that the secondary supplies were used apparently through hose and hydrants, or from risers, and that would be, of course, allowed even if there were a separation of the piping. The requirement of a separation of the piping would not have prevented the use of that supply in either of those two cases, or in most of the other cases. It strikes me that the city supply ought always to be sufficient to take care of the sprinkler system, and, if the factories desire, of course they can have a tank on the roof, or some further storage on that supply; and that the independent supply in fire mains, in hydrants, in risers with hose attachments, etc., could be absolutely independent, and still nearly as effective as now,— perhaps not quite, but nearly so. I believe we are coming to that universally, unless inventors get busy and do something that they haven't done yet for us.

Mr. French. Regarding what Professor Bemis has just said, it is true that at Paterson the protection was through hose streams. At the Cocheco Mills the fact that four or five pumps were immediately thrown on to the sprinklers, when several hundred sprinklers were opened, was a very large factor in checking the fire, and had it not been possible to put those pumps on at once I believe the fire would have been much more serious. The two cases fall, one in one class and the other in the other.

Now, regarding what Mr. Collins states, it is true that in several of the older mills of Lowell and Lawrence and some other places it is the practice to maintain the pump pressure during the day and sometimes at night against the city water; but those cases are the exceptions. I think in most places it would be entirely feasible and in every way desirable to make a complete separation between the pipes carrying water for drinking purposes and those carrying water from the river supply for toilets, boiler feeding, and such purposes, where cheaper water is desired. That would answer the point that Mr. Collins made. We do not believe it is proper to take water from the fire system, or from pipes connected

with the fire system in a mill, for drinking purposes, and a great many have already changed to an entirely separate drinking water system. I merely mention these things because they are points that, while a natural part of this discussion, are in no way an essential part of the settlement of the problem. The problem can be made a very clean, straight problem of a fire system used exclusively for fires, into which at rare occasions it is desired to pump water from an unlimited source like a river or a pond which may be polluted. In all those cases where drinking water is taken from the mill supplies, it is reasonable to insist that such uses be cut off entirely from the fire system.

A word as to what Mr. Lochridge said as to the possibility of two supplies. It is not possible to supply the sprinklers from one set of pipes and the hydrants from another set of pipes, and still have the secondary fire supply from the pumps on the sprinklers as well as the city water, unless you have the two systems together at times, and depend on some form of check-valve. Any double system of that nature — and we have put in many such — are likely to develop complications which, entirely beyond the question of cost, may be serious in case of fire.

Mr. J. H. Child. Mr. President, I should like to ask if the insurance interests are doing anything of their own volition in placing double checks, or doing anything along this line, or if it has not been the result of agitation from the water-works men.

Mr. French. Mr. President, I will answer that very gladly. The insurance interests are taking steps from their own experience, and to-day in practically every layout made in our association, where there is a possibility of pollution, a double check is included. We have spent a great deal of time and money in the development of the double check, and in the study of other and possibly better arrangements. I think if I could show you the whole history of what the underwriters have done, you would feel that they had certainly done a very large amount of work on this subject.

Mr. Child. I was speaking from my own experience, and with a system recently laid out, where I have seen no indication of a double check, and certainly the secondary system is decidedly polluted.

Mr. French. I don't know the case, but I should be very glad to look at it with you.

Mr. Sullivan. The fairness of the insurance people was shown in a case when they compromised with us, devoting considerable time in getting up some special devices. I think we ought to give the insurance people a little credit.

Mr. J. Walter Ackerman (*by letter*).* The city of Auburn, N. Y., a town of about 36 000 inhabitants, is situated in the central New York lake district, on the outlet of Owasco Lake. This lake has a drainage area of about two hundred square miles, and the topography of the city is such that there is about two hundred feet of fall in the outlet of the lake as it passes through the city, so that it furnishes a great deal of water power, and naturally many mills and factories were located on this stream during the development of the town. In fact, Auburn is classed as a manufacturing city.

In the spring of 1908, there was a small epidemic of typhoid fever. The water commissioners employed a sanitary expert to see if the source of it could be discovered, but his report, rendered some months later, which showed evidence of very careful research, did not show any positive proof of the source of the epidemic. However, on account of the fact that no other carrier was as common as the water supply, the probable cause of this epidemic was finally laid to the city supply. Further investigation by other sanitary experts failed to add any further information, and corroborated the first expert's opinion. Prior to the outbreak there had been several cases of fever on the watershed, but they were isolated from all streams and from each other, so that it did not seem probable that the epidemic came from them, and hence it was thought it must have come from some other accidental pollution.

The writer assumed the duties of superintendent of the Auburn water works in September of the same year, but was thoroughly familiar with the situation, as he had served in the capacity of city engineer for a period of six years. After being in office for a short time, it was learned that some of the men in the factories complained that they did not like the drinking water after a fire-

* Superintendent of Water Works, Auburn, N. Y.

drill. This lead to an investigation regarding the check-valves in different factories of the city, relative to whether they were working properly or not. However, in fairness to the above incident, I will say that the water which the factory operatives objected to did not come from a polluted source, as it was a tank supply coming directly from the city mains, but of course, standing there for long periods of time, without change, it became very unpalatable.

The municipal water supply of the city comes from Owasco Lake, being drawn at a point about 40 feet underneath the surface and about 2 000 feet from the foot of the lake. It is pumped from the lake directly into the suction pipe of the station, situated down in the city, through a 24-inch main about 9 000 feet in length. There is no intermediate reservoir or storage in any part of the system. The normal pressure carried on the city mains varies from 50 to 90 pounds, depending upon the locality. At all the mills and factories, I think the lowest pressure at any time is about 60, and perhaps increases to about 90, but at times of fire this pressure is increased by about 35 to 40 pounds.

In about a dozen of the factories, they have auxiliary fire-service equipment, of the following general type. In the street bordering the factory or mill site, the mains of the city distribution system, generally 12 inches in size, are located at a depth of about 5 feet underground; either at one or two points on this main, a connection is made from 4 to 12 inches in diameter, depending upon the amount of water needed for fire protection proportionate to the size of the factory. Most of the original installations, generally had an indicator post on the gate valve which closed the leader running into the factory, but which was used only at such times as repairs were being made, as the efficiency of the system depended upon this valve being open at all times for immediate use. After the water passed through the above-mentioned gate valve on its way to the factory, it next passed through a check-valve which was so placed as to allow the water to pass freely through it on the way to the factory, but which was supposed to close tightly if a current of water passed in the opposite direction back toward the city main.

When this examination of the check-valves was started, we

found that in general they were all buried underneath the ground and had never been inspected since being installed, and were left there without attention in the same way as the ordinary gate valve. However, some of the factories examined did have their check-valves in an accessible pit. After the water has passed through the check-valve on its way to the factory, it circulates through the yard system, which has on it several outside fire hydrants, and then into the building, and fills the automatic sprinkling pipes and the risers on which are attached the hose stands for use on the different floors of the factory. It should be noted in this connection that the city pressure is on all of the apparatus all of the time.

In order to comply with insurance requirements and to secure low insurance rates, the factory owner has to provide an auxiliary supply in addition to this system. This is accomplished by installing at some point in or adjacent to the factory a steam

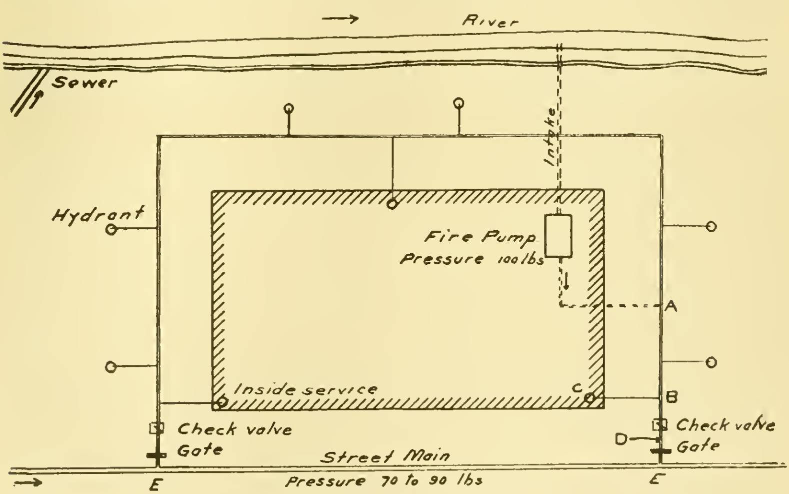


Diagram showing a Typical Arrangement of Connections for an Auxiliary Fire Supply in a mill in Auburn, N.Y. (After J. W. Ackerman)

FIG. 3.

fire pump, or other similar apparatus, capable of pumping water at a high pressure. The supply for this pump in this city generally comes from the Owasco River, on account of the fact that most of the factories are located on or near it. This river, flowing through the center of the town, receives the discharges from many sewers nearly the whole length of its course through the city; consequently the water is nothing more or less than dilute sewage. The discharge from this pump is connected with the main supply from the city mains at some point in the factory yard, so that the polluted water from the river joins the city water after the city water has passed through the check-valve on its way to the factory. This constitutes the typical fire-protection scheme with auxiliary supply. Fig. 3 shows a general installation.

The method of operation, according to insurance regulation, was to the effect that the fire pump was to be operated at least once per week, to see that everything was in working order. On being present at these tests, the writer found that the pump, taking its supply from the river above mentioned, would bring the entire factory supply system up to the pressure at which the relief of the pump was set, which ran from 100 to 120 pounds, so that at a time of testing, all of the pipes and mains in the factory were at the same pressure as that created by the pump. At such a time, even if there were any fires in the city, this pressure would always be more than that carried in the city main, consequently the inside pressure would tend to go out into the city main, if the check valve did not properly operate to prevent it. At the time of an actual fire at a factory, or an actual test of the entire system, as conducted by the insurance inspectors, the entire system is filled with polluted water, because the fire pump maintains, generally speaking, a higher pressure than the city system carries, and the different hose connections in operation would soon empty the supply of city water stored in them, which would be replaced by the polluted water of the river.

In order to study the situation, the factory owners very willingly uncovered all of the check-valves, and taps were inserted into the pipe lines between the check-valve and the gate valve with the post indicator before mentioned. Then by varying the pressures inside the factory, it could be determined whether water came

back through the check and out of this tap; many samples of water were collected. Some of these check-valves seemed to close absolutely tight; generally speaking, however, the larger the check-valve, the greater the leaks — and in some instances they were notoriously bad. Bacterial examinations which were taken at this time showed polluted water going back through the check-valve toward the city main.

After these examinations were concluded, Mr. George C. Whipple, of the firm of Hazen & Whipple, who was making a complete sanitary report on the entire system, was asked to examine the check-valves and look over the examinations already made. The result of his report was such that the water commissioners felt that contamination was liable to result from the continuance of the installation, as then existing, and so all factory and mill connections were ordered discontinued if the auxiliary supply was to be used in connection thereto. This, of course, met with strenuous opposition on the part of the factory owners, and after they appealed to their insurance interest, the insurance people recommended double check-valves in the place of the single ones previously used. This concededly better equipment was not endorsed, however, by the water commissioners, but critical examination of these double check-valves showed that there were many chances of improvement in design, as tuberculation of corroding surfaces was liable to cause the same condition of affairs as was found in the single check-valves.

On a request by the insurance and factory interests for a further conference, which was given them by the water commissioners, the matter was turned over to the commissioners' experts, Hazen & Whipple, and the experts representing the fire insurance companies. As a result of this joint conference, the commissioners modified their original order of discontinuance of the fire connection, but adopted a special design of double check-valve submitted by the experts of the insurance people; and, as the situation now stands, these specially designed and constructed double check-valves are to be installed on all fire-service connections to be placed in brick or concrete pits that are accessible for inspection, the inspection to be made by agents of the water board, the factory owner to pay all such expenses, the normal inspection

being to test for leakage; but at least every six months the valves are to be dismantled and examined to see if there is any chance for further improvement in design, or if they are in any way actually faulty under the present form.

The only unfortunate incident at the present time is the fact that only one manufacturer could be induced to take up the construction of these special check-valves, and a change of management has also somewhat delayed delivery. However, the writer is informed that other manufacturers are now looking up the question, and we hope that before long the entire equipment will be in operation.

MR. A. E. HANSEN* (*by letter*). Assuming Mr. French's theory that only a slight amount of unsafe water can enter the city mains by way of the interposed check-valves to be correct, it seems that he condemns his own side by this concession, since even a slight amount of water may contain — and if the secondary supply is seriously contaminated, undoubtedly will contain — millions of intestinal bacteria, a goodly number of which under certain conditions will be of the typhoid type. The introduction of these bacteria directly into the water mains is of much more serious consequence than would be their introduction into the supply at the head waters; no chance even for sedimentation is given, but a direct delivery of the germs to the adjacent consumers is established with no possibility of their removal. The question, then should not be slighted, but must be faced as one deserving the most serious consideration.

The ordinance of the Cambridge, Mass., water department, prohibiting the connection of any outside supply to the city water mains, as brought out by Mr. Brooks, is, in my opinion, the only proper attitude for water-works engineers and superintendents to take, and even Mr. French concedes that the supply of pure water must be the first consideration which takes precedence over all others.

New York has a secondary supply of salt water for the fire protection of the tall buildings. Nobody would think for a minute of cross-connecting this to the primary supply of Croton water, and there appears to be no necessity of it. A good many of the taller

* Sanitary Engineer, New York City.

loft buildings have sprinkling devices for fire protection which are way above the elevation to which the Croton supply would rise. These buildings have sprinkler and standpipe systems entirely separate from the general water-supply system, except that they are supplied from a tank on the roof filled automatically by a pump with Croton water. This tank supply furnishes the first water to the sprinklers. A Siamese hose connection is provided in the sprinkler and standpipe system on the sidewalk for the hose attachment of the fire engine, which upon its arrival pumps from a nearby fire hydrant to the standpipes and sprinklers.

It should not be difficult or prohibitively expensive to apply a similar method to the fire protection system of mills using a secondary supply in the following manner:

Provide a storage tank of sufficient size and elevation to meet the requirements of the Board of Fire Underwriters for the purpose of supplying the automatic sprinklers during the first stages of a fire.

Provide an approved fire pump automatically connected to start as soon as the water level falls in the tank; cross-connect the pump discharge with the standpipe and sprinkler system direct, and connect the pump suction to the secondary supply. Provide a check-valve on the fire line just below the tank, and a standard fire department Siamese connection for fire engine just outside of building.

Install, further, a permanent suction line from the secondary supply to a point near the Siamese plug, and fit same also with a standard fire engine hose thread for hose suction connection to the fire engine. All water used in the inside standpipe and sprinkler system would, therefore, be supplied from the secondary supply, whereas any water from the fire department hose service might be obtained from either the city or from the secondary supply.

Mr. French (*by letter*). It is evident that Mr. Hansen did not fully understand some of my statements. I did not agree for an instant that even a slight amount of unsafe water might enter the public mains, and I should certainly concur with him that under some conditions a small amount of polluted water might be a very serious danger.

The point is, that in a properly laid out system the only time when there would be a pressure against the check-valves in the service connection from the public mains higher than the pressure in the public mains would be during a severe fire, or occasional testing. In thoroughly protected risks severe fires are very rare, while all testing can be done in such a way that there is absolutely no possibility of getting polluted water into the public mains. Therefore, the periods during which trouble could possibly occur are infrequent and short and in many risks might not aggregate more than a few hours in ten or twenty years.

For these times we would have with the plans outlined two well-designed and well-cared-for check-valves, and the chances of both failing is in itself very remote. Again, during the possible severe fire the draft in the factory yard would be heavy so that the whole tendency is for the water to be flowing into the yard rather than out of it.

When, therefore, we couple all of these conditions together it is at once apparent that the chance of getting polluted water into the public mains is practically negligible and does not with any present light seem to justify the requirement of absolutely cutting off the public water from such fire systems.

The arrangement of supplies which Mr. Hansen suggests applies mainly to the city of New York and would not be applicable to the many manufacturing plants located throughout the country in small cities and towns, and very frequently almost entirely dependent upon their own equipment for heavy fire fighting. It will be recognized at once that a large percentage of our manufacturing properties are thus situated. In these cases, though the primary supply for sprinklers may come from public mains, the one, three, or possibly five thousand gallons per minute which might be needed at high pressure in case of a severe fire must come from their own fire pumps.

Again, it should be appreciated that while city buildings such as Mr. Hansen cites are practically always quite limited in area per floor, our great industrial development has required enormous areas in single buildings and to-day factories 150 feet in width, and 600 feet and even 800 feet in length, are not uncommon. In such plants under possible conditions a quick fire may open many

sprinklers, necessitating an ample primary water supply followed by most liberal reinforcing from fire pumps.

The plan which Mr. Hanson suggests would let the fire pump draw from an unlimited secondary supply, but in many cases where our primary supply is now furnished by a connection from public mains which give good pressure and ample quantity would compel giving up this good primary supply and substituting for it an elevated tank. In many instances no elevated tank possible would give the pressure or quantity of water which the public service gives, so that besides entailing considerable expense, this plan would result in materially weakening the efficiency of the protection.

Fire protection engineering has brought methods of preventing loss to a high state of efficiency and is making a decided stand to stop the enormous fire waste of this country. The best practice for large manufacturing plants has gone entirely beyond the limitations which Mr. Hansen suggests. It is therefore most desirable that this problem be very broadly considered, and certainly it is only reasonable to first see if experience will not show that along the lines of safeguarding suggested in the previous discussions it will not be found that there is ample protection against any danger of polluting our public supplies, and that with such protection we can continue to let public water be used for fire fighting work in the way which long study has shown permits its largest usefulness.

PROCEEDINGS.

PROVIDENCE, R. I., June 22, 1910.

The June meeting of the New England Water Works Association was held at Field's Point, Providence, on June 22, 1910.

The following members and guests were present:

MEMBERS.

J. H. Ayres, L. M. Bancroft, F. A. Barbour, A. E. Blackmer, G. A. P. Bucknam, T. J. Carmody, J. C. Chase, J. H. Child, C. E. Childs, R. C. P. Coggeshall, John Doyle, E. D. Eldredge, J. W. Ellis, A. N. French, F. L. Fuller, F. J. Gifford, C. W. Gilbert, F. H. Gunther, F. E. Hall, A. E. Hansen, F. T. Kemble, Willard Kent, G. A. King, A. R. McCallum, Thomas McKenzie, John Mayo, F. H. Mills, H. D. Pease, E. M. Peck, C. E. Peirce, J. J. Philbin, A. L. Sawyer, W. H. Sears, E. M. Shedd, G. H. Snell, G. T. Staples, W. M. Stone, H. L. Thomas, W. H. Thomas, D. N. Tower, C. H. Tuttle, G. E. Winslow, and I. S. Wood. — 43.

ASSOCIATES.

Harold L. Bond Company, by H. P. J. Earnshaw; Builders Iron Company, by F. N. Connet; Chapman Valve Manufacturing Company, by H. L. DeWolf and A. W. Hobbs; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; Gamon Meter Company, by W. H. Buckley; International Steam Pump Company, by Samuel Harrison; Lead-Lined Iron Pipe Company, by T. E. Dwyer; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; Norwood Engineering Company, by H. W. Hosford and C. E. Childs; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall, E. K. Otis, and E. P. King; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by H. M. Heim; R. D. Wood & Company, by W. F. Woodburn. — 23.

GUESTS.

Mr. E. S. Locke, Superintendent, Water Works, Lexington, Mass.; Fred. A. Hall, Inspector, Haverhill, Mass.; A. W. Dunbar, Hyde Park, Mass.; D. K. Bartlett, Whitman, Mass.; Mrs. I. G. Wood, Miss M. E. Wood, Wm. H. Patterson, O. F. Clapp, J. A. McKenna, J. E. Bowen, J. W. Bugbee, and F. P.

Gorham, Providence, R. I.; John J. Phelan, Worcester, Mass.; J. W. Wixtead, East Douglass, Mass.; William Fay, Worcester, Mass.; Mrs. George T. Staples, Dedham, Mass.; Mrs. H. W. Hosford, Florence, Mass.; Mrs. C. E. Peirce, East Providence, R. I.; F. O. Clapp, Asst. Engr., Providence, R. I.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. T. J. Carmody, Mrs. J. J. White, Miss Alice S. Corner, Miss Catherine Sullivan, Holyoke, Mass.; Severance Burrage, Prof. Sanitary Science, Purdue University, Lafayette, Ind.; H. A. Seymour, Warren, R. I.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. John Mayo and Miss Sarah W. Mayo, Bridgewater, Mass.; Peter J. Cannan, Water Registrar, Clinton, Mass.; Mrs. Frank J. Gifford, Fall River, Mass., and Wm. R. Edwards, East Jersey Water Company, Paterson, N. J. — 32.

Upon recommendation of the Executive Committee the following-named applicants were elected to membership in the Association: Henry F. Bryant, engineer, Brookline, Mass.; Edward J. Looney, superintendent water works, Belmont, Mass.; Frank A. Sampson, superintendent water works, Kingston, Mass.; A. F. Sickman, hydraulic engineer, Holyoke Water Power Company, Holyoke, Mass.; Charles E. Ratz, superintendent Water Company, Punxsutawney, Pa.; Bernard M. Wagner, engineer, in charge of Construction Water Department, Rockville Center, L. I.; J. H. Bridges, superintendent water company, Henderson, N. C.; Wm. H. C. Ramsey, superintendent Citizens Light, Heating and Power Company, Johnstown, Pa.; William W. Seymour, Provident Building, Tacoma, Wash.; John A. Burgan, water commissioner, Hammonton, N. J.; Richard W. Rea, hydraulic engineer, Seattle, Washington; Fred C. Dunlap, chief engineer, Bureau of Water, Philadelphia, Pa.; George Holtzmann, superintendent water works, Schenectady, N. Y. — 13.

Adjourned.

WILLARD KENT, *Secretary.*

EXECUTIVE COMMITTEE.

JUNE 22, 1910.

A meeting of the Executive Committee was held on the steamer *Squantum*, en route to Field's Point, Providence, R. I., the occasion being the June Outing.

Present: President George A. King, and members Lewis M. Bancroft, Ermon M. Peck, and Williard Kent.

The following applications for membership were received and considered, and it was voted that all of said applicants be recommended for membership in the Association. Henry F. Byrant, engineer, Brookline, Mass.; Edward J. Looney, superintendent water works, Belmont, Mass.; Frank A. Sampson, superintendent water works, Kingston, Mass.; A. F. Sickman, hydraulic engineer, Holyoke Water Power Company, Holyoke, Mass.; Charles E. Ratz, superintendent water company, Punxsutawney, Pa.; Bernard M. Wagner, engineer in charge construction, Water Department, Rockville Center, L. I.; J. H. Bridges, superintendent water company, Henderson, N. C.; Wm. H. C. Ramsey, superintendent Citizens Light, Heating, and Power Company, Johnstown, Pa.; William W. Seymour, Provident Building, Tacoma, Wash.; John A. Burgan, water commissioner, Hammonton, N. J.; Richard W. Rea, hydraulic engineer, Seattle, Wash.; Fred C. Dunlap, chief engineer, Bureau of Water, Philadelphia, Pa.; George Holtzmann, superintendent water works, Schenectady, N. Y. — 13.

The matter of the expense incurred by the Committee on Uniform Accounting was considered and it was voted that bill for said expenses be approved and ordered paid.

Adjourned.

WILLARD KENT, *Secretary.*

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXIV. December, 1910. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER-WORKS STATISTICS FOR THE YEAR 1909, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY RICHARD K. HALE, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The tables presented herewith contain statistics of forty-five municipal water works, as summarized in their annual reports. There are other water works which summarize their statistics, but the compiler has not succeeded in obtaining their reports for the year 1909.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	Reference to Journal.
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65

Statistics for	Reference to Journal.
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277
1904	Vol. XIX, p. 241
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In the various tabulations, statistics are given for the following places and years:

Place.	Year.
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904, 1906, 1909
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904, 1906, 1909
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04, 1906
Beverly, Mass.	1903, 1906
Billerica, Mass.	1899–1904, 1906, 1909
Boston, Mass.	1886–94, 1897, 1900, 1903, 1909
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904, 1906, 1909
Burlington, Vt.	1886–1904, 1906, 1909
Cambridge, Mass.	1900–04, 1906, 1909
Chelsea, Mass.	1900–04, 1906, 1909
Cleveland, Ohio	1902–04, 1906
Concord, N. H.	1895, 1898, 1900–04
Detroit, Mich.	1909
Dover, N. H.	1900, 1909
East Orange, N. J.	1909
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904, 1906, 1909
Fitchburg, Mass.	1886–92, 1894–1904, 1906, 1909
Framingham, Mass.	1909
Freeport, Me.	1901
Geneva, N. Y.	1900
Gloucester, Mass.	1906, 1909
Harrisburg, Pa.	1906, 1909
Haverhill, Mass.	1900, 1904, 1906, 1909
Holyoke, Mass.	1886–92, 1897–98, 1900–04, 1906, 1909
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04, 1909

Place.	Year.
Lawrence, Mass.	1902–04, 1909
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900
London, Ontario	1909
Louisville, Ky.	1909
Lowell, Mass.	1886, 1897–1904, 1906, 1909
Lynn, Mass.	1888–98, 1900–04, 1906
Madison, Wis.	1900, 1902–04, 1906, 1909
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04, 1906, 1909
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04, 1906, 1909
Middleboro, Mass.	1895–1904, 1906
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04, 1906
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904, 1906, 1909
New London, Conn.	1886–1904, 1906, 1909
Newton, Mass.	1888–1904, 1906, 1909
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904, 1906
Plymouth, Mass.	1886–1904, 1906, 1909
Portland, Ore.	1909
Providence, R. I.	1897–1904, 1906
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904, 1906, 1909
Reading, Pa.	1901–04, 1906, 1909
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schnectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04, 1906, 1909
Springfield, Mass.	1886–1904, 1906, 1909
Sydney, Cape Breton	1909
Taunton, Mass.	1886–1904, 1906
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904, 1906
Ware, Mass.	1886, 1888–92, 1900–04, 1906, 1909
Watertown, Mass.	1900, 1909
Wellesley, Mass.	1888–93, 1898–1904, 1906, 1909
Westerly, R. I.	1902–04, 1906, 1909
Whitman, Mass.	1897–1904, 1906
Wilmington, Del.	1900
Winchendon, Mass.	1900–04, 1906, 1909
Woburn, Mass.	1900–04, 1909
Woonsocket, R. I.	1886–1900, 1902–04, 1906, 1909
Worcester, Mass.	1900, 1906, 1909
Yonkers, N. Y.	1893–96, 1900–04, 1906

1909. — TABLE 1. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1	2. — Description of fuel used.				
						Builders of pumping machinery.	*a* Kind.	*b* Brand of coal.	*c* Av. price per gross ton.	*d* Per cent. of ash.	*e* Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	....	....	....	....	...	..	....
2	Attleboro, Mass.	1873	Town.	Wells.	Pumping.	Deane, Barr.	Bituminous.	....	....	..	....
3	Billerica, Mass.	1898	Town.	Driven wells.	Pumping.	Barr.	Bituminous.	Pocahontas. New River. Orenda.	$4 52	..	....
4	Boston, Mass.	1848	City.	Metropolitan W.W.	....	....	....	....	....	..	....
5	Brockton, Mass.	1880 1902	City.	Silver Lake.	Pumping.	Barr, Holly.	Bituminous.	New River.	4 45	9.1	....
6	Burlington, Vt.	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	....	3 80	..	....
7	Cambridge, Mass.	1855	City.	Hobbs Brook, Stony Brook, Fresh Pond.	Pumping.	Groshon, Worthington, Blake.	Bituminous.	Georges Cr. Orenda. New River.	3 90 3 68 3 90	..	....
8	Chelsea, Mass.	1867	City.	Metropolitan W.W.	....	....	....	....	....	..	....
9	Detroit, Mich.	1827	Water Com'rs.	Detroit River.	Pumping.	Detroit Loco., Riverside, Eng., Allis.	Bituminous.	Meadow Bk.	2 55	6.7	...
10	Dover, N. H.	1888	City.	Pond and springs.	Pumping.	Blake, Platt, Lawrence.	....	Cumberland.	4 75	..	....
11	E. Orange, N. J.	1882	City.	Wells.	Pumping.	Snow.	Buckwheat.	Scranton.	2 75	18	....
12	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland. Georges Cr.	....	..	....
13	Fitchburg, Mass.	1873	City.	Storage reserv'rs.	Gravity.	....	....	....	....	..	....
14	Framingham, Mass.	1885	Town.	Filter galleries, Sudbury Aque.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 15	10	....

15	Gloucester, Mass.	1884	City.	Reservoirs.	Pumping.	Knowles, Barr.	Bituminous.	Georges Cr.	4 25	8	....
16	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg	Anthracite.	Pea.	1 25	17	....
17	Haverhill, Mass.	..	City.	Ponds.	Gravity and pumping.	Worthington, Deane, Barr, Platt, Laidlaw-Dunn-Gordon.	Bituminous.	Cumberland. Carbon.	4 71	..	....
18	Holyoke, Mass.	1873	City.	Lakes, reservoirs and Manhan R.	Gravity.	....	....	....	....	..	....
19	Keene, N. H.	1868	City.	Lakes.	....	....	....	....	....	..	....
20	Lawrence, Mass.	1874	City.	Merrimac River.	Pumping.	Barr, Morris.	Bituminous.	New River.	4 45	6.5	....
21	London, Ontario.	1878	City.	Springs.	Pumping.	Northey,* Kelly, Blake-Yates.	Steam.	W. Virginia.	4 25	..	....
22	Louisville, Ky.	1860	City.	Ohio River.	Pumping.	Cornish, Morris, Allis-Chalmers, Holly.	Bituminous.	E. Kentucky.	1 70 1 34	..	....
23	Lowell, Mass.	1870	City.	Driven wells.	Pumping.	Morris, Worthington, Deane, Knowles, Holly.	Bituminous.	Pocahontas. New River.	4 44	..	....
24	Madison, Wis.	1882	City.	Artesian wells.	Pumping.	Allis-Chalmers, Knowles.	Anthracite.	Pea.	7 10	..	....
25	Marlboro, Mass.	1883	City.	Lake and res.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	4 70	..	....

* Hydraulic.

1909. — TABLE 1, *Continued.* — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1. Builders of pumping machinery.	2. — Description of fuel used. a. Kind.	b. Brand of coal.	c. Av. price per gross ton.	d. Per cent. of ash.	e. Wood. Price per cord.
26	Metropolitan Water Works, Mass.	1848 1872 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 75%. Gravity, 25%.	*Chestnut Hill*	*High Service*	*Station.*			
						Holly, Allis, Quintard.	Bituminous.	New River. Blossburg. Imperial. Vulcan. Logan.	(1) $3 85 to 4 19	9.5	....
							Anthracite.	Buckwheat.	2 73	..	....
						Chestnut Hill	*Low Service*	*Station.*			
						Holly.	Bituminous. Anthracite.	Vulcan. Buckwheat.	(2) 3 86 to 4 06 2 61	9.6	....
						Spot Pond	*Station.*				
						Blake, Holly.	Bituminous. Anthracite.	Davis. Screenings.	(3) 4 19 to 4 25 2 24 to 2 50	13.2	....
27	New Bedford, Mass.	1866	City.	Ponds.	Pumping.	Dickson.	Bituminous.	New River.	4 04	7	....
28	New London, Conn.	1872	City.	Lake and Res.	Gravity and pumping.	....	....	....	....	..	....
29	Newton, Mass.	1876	City.	Collecting Gallery.	Pumping.	Barr, Worthington.	Bit'm's, 64%. Anth., 36%.	Radcliff. New River. Screenings.	3 79	14	$6 00
30	Plymouth, Mass.	1855	Town.	Ponds.	Gravity and pumping.	Barr, Worthington.	Bituminous.	Various.	5 00	..	....
31	Portland, Ore.	1893	City.	Bull Run River.	Gravity and pumping.	Smith & Vail, Gould, Holly, Reidler, Worthington.	Pumps operated by Pelton wheels.	....	....	..	....

32	Reading, Mass.	1891	Town.	Filter gallery.	Pumping.	Blake.	Bituminous.	....	4 75	..	....
33	Reading, Pa.	1819	City.	Creeks and springs.	Gravity and pumping.	Worthington, Allis-Chalmers.	Bituminous.	....	2 53	8.1	3 50
34	Somerville, Mass.	1868	City.	Metropolitan W. W.	....	....	....	....	....	..	....
35	Springfield, Mass.	1864	City.	Res. and Little R.	Gravity.	....	....	....	....	..	....
36	Sydney, C. B.	1892	City.	Reservoirs.	Gravity.	....	....	....	....	..	....
37	Taunton, Mass.	1876	City.	Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr. Cumberland.	4 80 4 45	..	....
38	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	....	5 00	..	4 50
39	Watertown, Mass.	1884	Town.	Metropolitan.	....	....	....	... .	....	..	....
40	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	New River.	4 20	11.8	3 50
41	Westerly, R. I.	1886	Town.	Driven wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	5 00	..	....
42	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake, Laidlaw-Dunn-Gordon.	Bituminous.	....	4 70	12.3	....
43	Woburn, Mass.	1872	City.	Filter gallery.	Pumping.	Worthington, Blake.	Bituminous.	....	4 92	9	....
44	Woonsocket, R. I.	1884	City.	Crook Fall Brook.	Pumping.	Worthington, Deane, Builders I. Fdy.	Bituminous.	Pocahontas.	4 58	9.1	3 00
45	Worcester, Mass.	1845	City.	Reservoirs	Gravity.	....	....	....	....	..	....

[1] Average price per gross ton, $3.70.
[2] Average price per gross ton, $3.44.
[3] Average price per gross ton, $3.43.

1909. — TABLE 1, *Concluded.* — PUMPING STATISTICS.

	3	4	4a	5	6	7	8	9	10	11	12
Number.	Coal consumed for the year. (Lbs.)	Lbs. of wood ÷ 3 = equivalent coal.	Amount of other fuel used.	Total equivalent coal consumed for the year. (Lbs.) (3) + (4).	Total pumpage for the year in gallons.	Average static head against which pumps work. (Feet.)	Average dynamic head against which pumps work. (Feet.)	Number of gallons pumped per lb. of equivalent coal.	Duty in foot-pounds per 100 pounds of coal. No deductions.	Cost per million gallons pumped into reservoir, figured on pumping station expenses.	Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	1 044 639	.....	......	1 044 639	301 612 468	...	261	289	71 020 000	......	......
3	360 985	.....	......	360 985	39 748 276[1]	300	322	132	29 656 316	$57 31	$0 18
5	2 203 268	.....	......	2 203 268	856 290 553[1]	202	302	388	97 997 061	11 57	0 04
6	2 783 986	.....	......	2 783 986	364 864 346[1]	289	316	131	34 539 616	24 74	0 08
7	4 642 700	500	......	4 643 200	5 678 588 720[1]	157	189	792	125 084 465	4 69	0 02
9	36 066 844	.....	......	36 066 844	27 816 750 890[2]	...	132	771	87 945 076	3 33	0 01
10	210 735	......	193 203[3]	....	272 805 000[1]	159	182	289	43 512 435	17 12	0 09
								1 095	166 345 758		
11	4 249 700	.....	......	4 249 700	1 155 614 900	204	217	272	49 400 000	15 89	0 07
12	4 258 000	.....	......	4 258 000	1 949 261 817	186	...	409	....	8 77	....
14	916 400	200	......	916 600	205 453 000[2]	201	205	224	38 484 918	20 79	0 10
15	937 737	.....	......	937 737	502 204 723[1]	117	140	502	62 530 777	13 67	0 10
16	10 416 138	.....	......	10 416 138	3 659 543 150[1]	200	235	363	72 329 958	4 51	0 02
17	2 169 164	.....	......	2 169 164	1 104 690 737[2]	190	204	290	86 645 206	12 63	0 62
								589			
20	288 788	.....	......	288 788	94 957 360	293	321	329	88 009 276	24 78	0 08
	2 420 254	.....	......	2 420 254	1 206 390 311	154	186	497	76 478 736	10 80	0 06
21	2 994 700	.....	......	2 994 700	1 561 355 262[4]	...	240	274	54 786 260	8 35	0 04
22	12 930 589	.....	......	25 317 485	9 111 827 126	...	199	705	111 767 000	3 44	0 02
	12 386 896				7 957 890 859	...	112	642	60,500 000	2 82	0 02
23	5 546 723	2 400	......	5 549 123	1 909 792 832	157	164	344	78 340 873	16 29	0 10
24	3 370 700	.....	......	3 370 700	617 317 000	201	231	...	....	42 69	0 18
25	842 322	.....	......	842 322	208 933 300[2]	173	176	...	41 370 654	18 50	0 10
*26a	2 124 272	.....	......	2 124 272	1 321 950 000a	...	120	622	64 270 000	5 68	0 05
b	1 565 681	.....	......	1 565 681	1 404 590 000[2]	...	128	897	103 220 000	4 65	0 04
c	8 625 393	.....	......	8 625 393	10 708 460 000[2]	...	130	1 241	138 840 000	3 03	0 02
d	7 160 584	.....	......	7 160 584	19 183 420 000[2]	...	46	2 679	105 380 000	1 68	0 04
e	2 424 886	.....	......	2 424 886	2 693 510 000[2]	...	130	1 111	123 760 000	5 22	0 04
27	3 104 725	.....	......	3 104 725	2 718 298 758[2]	168	184	875	134 757 873	6 61	0 04

29	2 061 680	2 000	0	2 063 680	855 175 662[2]	234	263	414	90 893 908	11 84	0 04
30	431 940	.....	......	431 940	249 968 100	65	70	589	25 558 000	11 51	0 16
								438	34 340 000		
31	....	.....	......	....	....	175 to 565	150 to 570	...	....	......	......
32	580 249	.....	......	580 249	67 920 004[2]	219	240	117	23 429 369	44 05	0 18
33	7 246 500	1 800	......	7 248 300	2 905 448 577[1]	212	287	401	95 878 721	5 28	0 02
37	2 208 500	.....	......	2 208 500	792 767 691[2]	...	...	...	....	10 93	....
38	811 820	1 100	......	815 920	158 447 880[1]	230	252	194	40 923 955	29 10	0 12
40	722 100	100	......	722 200	118 198 000	260	280	164	38 219 000	30 29	0 11
41	1 449 312	.....	......	1 449 312	246 059 400[2]	217	232	176	32 850 000	26 53	0 11
42	402 007	.....	......	402 007	53 246 636[2]	246	289	132	31 924 000	30 11	0 10
43	2 469 200	.....	......	2 469 200	660 405 240[2]	214	216	267	48 292 334	15 22	0 07
44	1 134 900	1 729	......	1 136 629	542 596 731[1]	226	246	477	97 939 887	10 58	0 04

*29a. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engines 8 and 9.

a. Kirtland Street Station.

[1] Without allowance for slip.
[2] With allowance for slip.
[3] K.W.
[4] Imperial gallons. 646 319 273 imperial gallons pumped by water power.

1909. — TABLE 2. — FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts. Balance brought forward. a From ordinary receipts.	b From extraordinary receipts.	Water rates. A Fixture rates.	B Meter rates.	C Total from consumers.	Municipal departments. D For hydrants.	E For fountains.
1	Arlington, Mass.	....	....	$14 600 78	$24 017 62	$38 618 40	....	....
2	Attleboro, Mass.	$2 549 80	....	....	....	42 055 27	....	....
3	Billerica, Mass.	....	....	1 245 66	3 421 13	4 666 79	$2 300 00	....
4	Boston, Mass.	....	....	1 348 800 77	1 260 301 62	2 609 102 39	....	....
5	Brockton, Mass.	....	$35 704 35	459 00	109 474 53	109 933 53	....	....
7	Cambridge, Mass.	....	....	....	....	361 896 86	....	....
8	Chelsea, Mass.	....	....	38 085 26	71 919 12	110 004 38	....	....
9	Detroit, Mich.	72 879 98	....	398 220 75	229 956 90	628 177 65	....	....
10	Dover, N. H.	9 434 14	....	11 648 98	16 797 25	28 446 23	....	....
11	East Orange, N. J.	8 683 80	16 083 92	103 081 84	23 352 91	126 434 75	....	....
12	Fall River, Mass.	27 993 73	....	2 364 23	203 072 82	205 437 05	....	....
13	Fitchburg, Mass.	....	....	13 489 94	67 993 90	....	....	....
14	Framingham, Mass.	....	....	1 875 56	29 711 57	31 587 13	3 733 11	$280 00
15	Gloucester, Mass.	1 251 43	....	74 136 50	19 921 91	94 058 41	....	....
16	Harrisburg, Pa.	....	....	29 570 53	155 442 30	185 012 83	....	....
17	Haverhill, Mass.	34 772 28	....	72 129 85	27 412 97	99 542 82	....	....
18	Holyoke, Mass.	15 758 30	....	81 555 96	33 417 64	114 973 60	....	....
19	Keene, N. H.	....	....	....	....	28 324 32	6 525 00	500 00

20	Lawrence, Mass.	8 677 12	....	....	....	129 637 41	....	....
22	Louisville, Ky.	....	....	401 633 31	300 455 30	702 088 61	....	....
23	Lowell, Mass.	....	....	23,964 98	163 053 40	187 018 38	....	....
24	Madison, Wis.	399 85	5 125 14	....	....	40 652 44	....	....
25	Marlboro, Mass.	338 30	....	10 310 29	28 801 06	39 111 35	6 760 00	....
27	New Bedford, Mass.	37 203 33	22 662 28	77 928 99	142 079 55	220 008 54	....	....
28	New London, Conn.	53 901 04	....	....	....	63 499 36	13 680 00[1]	900 00[1]
29	Newton, Mass.	7 335 00	13 066 66	1 822 00	138 965 00	140 787 00	....	....
30	Plymouth, Mass.	2 686 46	....	....	....	36 611 90	....	....
31	Portland, Ore.	110 968 72	....	....	....	570 730 60	....	....
32	Reading, Mass.	279 67	....	....	13 813 55	13 813 55	5 040 00	300 00
33	Reading, Pa.	62 426 97	203 917 66	160 018 64	70 453 63	230 472 27	....	....
34	Somerville, Mass.	....	....	113 341 33	109 773 59	223 114 92	....	....
35	Springfield, Mass.	82 267 95	179 084 19	101 335 37	197 114 11	298 449 48	30 250 00[1]	645 00[1]
37	Taunton, Mass.	....	2 711 75	....	....	78 555 25	....	....
39	Watertown, Mass.	1 975 14	533 78	....	49 858 08	49 858 08	....	....
40	Wellesley, Mass.	4 771 82	2 566 39	240 00	18 573 15	18 813 15	4 000 00[2]	....
41	Westerly, R. I.	6 467 37	....	2 789 32	27 530 09	30 319 41	3 278 45	....
42	Winchendon, Mass.	6 302 05	....	35 00	8 818 30	8 853 30	4 960 00	333 33
43	Woburn, Mass.	....	....	41 788 19	11 359 51	53 147 70	....	275 00
44	Woonsocket, R. I.	....	....	2 472 66	83 244 15	85 716 81	18 685 00	2 111 94

[1] Book account only.

[2] Includes fountains and street watering.

1909. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number.	Receipts — *Continued.* Municipal departments — *Continued.* F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from municipal departments.	K From tax levy.	L From bond issue.	M From other sources.	N Total receipts.
1	....	....	....	....	....	$7 000 00	$2 000 00	$6 188 09	$53 736 49
2	....	....	....	$6 200 00	....	....	15 000 00	....	65 805 07
3	....	$159 98	$13 00	....	$2 472 98	4 548 33	....	157 71	11 845 81
4	....	....	....	....	....	218 563 49	....	69 969 60	2 897 635 48
5	$2 000 00	....	779 19	....	2 779 19	....	62 500 00	8 080 29	218 997 36
7	....	....	....	....	....	....	....	21 839 15	383 736 01
8	....	....	....	20 000 00	20 000 00	....	....	2 140 16	132 145 54
9	....	....	....	....	....	75 000 00	300 000 00	103 823 98	1 179 881 61
10	....	....	....	....	....	4 000 00	....	1 852 55	43 732 92
11	....	....	....	....	....	....	....	23 953 98	175 156 45
12	....	....	....	....	....	....	....	5 538 86	238 969 64
13	....	....	....	....	....	....	....	7 183 82	88 667 66
14	827 89	361 16	....	....	5 205 16	....	40 188 00	2 380 93	79 361 22
15	....	....	....	....	17 855 00	....	32 770 37	3 446 24	149 774 62
16	....	....	....	....	....	....	....	4 170 26	189 183 09
17	....	....	....	....	....	....	....	....	145 663 35
18	....	....	....	....	....	....	....	8 442 92	139 174 82
19	2 000 00	250 00	50 00	....	9 375 00	....	....	....	37 699 32

20	1 841 17	...	...	...	1 841 17	...	...	9 618 27	149 773 97
22	...	...	...	...	...	...	...	8 129 34	710 217 95
23	1 500 00	4 031 46	...	...	5 531 46	17 800 00	...	20 165 31	230 518 15
24	...	...	...	...	...	10 000 00	35 108 89	4 674 32	95 963 02
25	...	181 04	32 48	...	6 973 52	...	...	2 155 07	48 578 24
27	...	...	...	...	...	...	...	...	279 874 15
28	2 500 00[1]	1 500 00[1]	...	...	18 580 00[1]	...	...	...	135 980 40
29	550 00	2 888 00	...	...	3 438 00	...	...	...	164 626 66
30	...	...	...	...	...	...	12 053 87	1 013 95	52 366 18
31	...	...	...	...	...	...	250 000 00	5 217 50	936 916 82
32	500 00	...	...	860 00	6 700 00	...	4 350 00	1 641 60	26 754 82
33	[2]	...	...	...	...	...	208 763 29	11 039 05	716 619 24
34	...	...	...	...	...	...	...	15 076 10	238 191 02
35	7 116 12[1]	14 645 53[1]	5 424 05[1]	...	58 080 70[1]	...	1 103 778 51	57 284 49	1 778 945 32
37	...	...	...	...	...	22 000 00	...	6 110 31	109 377 31
39	...	...	...	9 600 00	9 600 00	...	...	1 644 72	63 611 72
40	[3]	261 10	...	...	4 261 40	...	15 461 34	1 850 44	47 724 54
41	13 68	...	...	...	3 292 13	...	...	2 125 94	42 501 85
42	168 54	...	...	...	5 461 87	8 200 00	...	15 50	28 862 72
43	250 00	255 00	...	...	780 00	...	...	...	49 928 11
44	2 035 39	1 775 64	741 84	10 000 00	35 352 81	...	...	3 863 41	124 933 03

[1] Book account only. [2] Included in meter rates. [3] Included in "Hydrants."

1909. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number.	Maintenance Expenditures. AA Operation.	BB Special.	CC Total maintenance.	DD Interest on bonds.	EE Payment of bonds.	FF Sinking fund.	Construction Expenditures. GG Extension of mains.	HH Extension of services.	II Extension of meters.	JJ Special.	KK Total construction.
1	$6 898 44	$17 442 46[1]	$24 340 90	$13 920 00	......	$10 000 00	$2 000 00	$983 74	$1 298 98	....	$4 282 72
2	......	....	36 062 59	......	......	10 000 00	11 631 61	3 486 97	1 454 61	$3 092 19	19 665 38
3	......	....	2 936 26	3 600 00	......	1 800 00	2 866 29	205 59	2 20	....	3 074 08
4	......	....	871 367 43	161 963 39	......	....	......	......	......	....	(*A*)
5	42 510 72	....	42 510 72	63 641 25	......	6 548 63	33 171 52	6 840 60	3 490 28	39 960 00	83 462 40
7	......	....	73 930 64	145 050 25	$12 500 00	120 999 50	......	......	1 999 86	33 681 73	35 681 59
8	8 686 93	51 499 13[1]	60 186 06	12 000 00	......	5 409 00	......	......	8 219 20	26 856 20	....
9	......	....	182 163 74	37 273 50	10,000 00	75 000 00	764 971 99	......	14 653 03	41 777 68	821 402 70
10	12 039 57	....	12 039 57	9 755 86	5 000 00	....	877 67	1 272 48	662 07	8 701 55	11 513 77
11	45 765 37	14 482 77	60 248 14	35 850 00	......	18 000 00	12 815 00	......	1 032 80	20 564 52	34 412 32
12	......	....	60 444 89	51 730 00	......	39 835 00	24 990 22	4 343 14	......	43 614 67	72 948 01
14	......	....	12 894 38	18 010 00	......	....	18 305 63	(*A*)	4 670 65	6 145 49	29 121 77
15	......	....	22 295 78	40 955 00	50 000 00	....	1 106 88	7 082 60	......	5 135 03	13 324 51
16	49 260 54	16 284 87	65 545 41	31 676 00	......	39 888 30	......	......	......	....	....
17	27 890 72	....	27 890 72	38 640 00	5 000 00	18 000 00	12 048 57	5 833 60	1 964 79	9 208 48	29 055 44
18	......	....	131 768 45	13 750 00	......	10 000 00	5 412 63	......	350 00	9 652 09	15 414 68
19	......	....	2 214 35	3 742 50	......	....	......	......	......	....	....

20	44 219 96	17 692 04	61 912 00	28 480 00	......	16 457 65	......	......	......	....	28 837 42
22	......	....	217 611 56	79 034 63	......	....	......	......	......	....	....
23	118 333 70	....	118 333 70	44 571 00	15 200 00	17 800 00	10 714 90	5 236 08	......	....	15 950 98
24	22 844 94	3 333 69	26 178 63	......	......	....	......	......	......	....	21 640 06
25	9 999 46	200 00	10 199 46	20 800 00	......	....	......	......	......	....	2 531 79
27	55 129 78	....	55 129 78	62 980 00	30 000 00	28 338 00	33 434 83	12 489 18	13 134 60	228 14	59 286 75
28	11 940 49	....	11 940 49	23 665 00	......	....	7 173 40	901 45	1 877 85	7 591 49	17 544 19
29	22 222 00	6 525 00	28 747 00	54 338 00	4 000 00	34 000 00	17 938 37	12 411 29	3 778 38	13 413 32	47 541 36
30	......	....	11 144 01	5 820 48	11 666 66	....	14 926 65	449 92	203 50	4 858 85	20 438 92
31	103 834 99	....	103 834 99	160 000 00	......	63 000 00	50 378 62	......	84 643 74	188 896 88	323 919 24
32	7 266 31	718 42	7 984 73	7 625 00	1 000 00	....	6 663 04	2 664 49	634 28	133 45	10 095 26
33	65 614 23	1 224 00	66 838 23	35 980 00	......	50 023 85	28 741 95	987 73	5 381 04	258 263 62	293 374 34
34	25 733 77	11 281 41	37 015 18	2 460 00	6 000 00	....	7 553 90	4 279 06	6 131 44	....	18 014 40
35	67 198 58	26 750 10	93 948 68	58 875 00	......	30 454 47[2]	111 153 39	......	......	1 092 277 12	1 203 430 51
37	......	....	33 574 77	33 890 00	......	11 977 34[2]	8 980 09	3 807 10	1 517 17	14 774 71	29 079 07
39	4 736 08	15 758 18[1]	20 494 26	11 400 00	14 000 00	....	2 952 94	2 946 33	1 151 99	....	7 051 26
40	7 704 60	113 79	7 818 39	11 280 00	......	....	4 679 45	1 012 19	......	12 343 36	18 035 00
41	11 129 57	....	11 129 57	13 368 39	......	6 000 00	2 510 67	1 452 13	570 89	2 030 84	6 564 53
42	4 564 59	....	4 564 59	3 040 00	......	....	6 260 03	363 28	506 88	6 080 97	13 211 16
43	......	....	20 607 56	2 780 00	......	25 782 84[2]	......	......	......	....	757 71
44	18 151 06	....	18 151 06	......	......	....	......	......	......	....	10 718 43

[1] Metropolitan water-works assessment. [2] Maintenance balance. (A) Included in maintenance.

1909. — TABLE 2, *Concluded.* — FINANCIAL STATISTICS

Number.	LL Unclassified expenses.	MM Balance. aa Ordinary	bb Extraordinary.	N Total.	Disposition of balance.	O Net cost of works to date.	P Bonded debt at date.	Q Value of sinking fund.	R Average rate of interest. Per cent.
1	....	$1 192 87	....	$53 736 49	....	$538 737 48	$355 000 00	$78 000 00	4
2	....	77 10	....	65 805 07	....	713 180 14	552 000 00	.74 794 56	.....
3	....	....	$435 47	11 845 81	....	95 793 44	90 000 00	....	.....
4	$1 864 204 66	....	....	2 897 635 48	....	15 593 943 60	3 696 500 00	3 205 159 65	3.89
5	....	22 834 36	....	218 997 36	Forward.	1 874 851 28	1 702 500 00	624 903 27	3.7
7	4 307 08	....	....	....	....	6 491 201 12	3 751 600 00	1 892 859 62	3½–4
8	18 55	13 811 82	5 644 71	132 145 54	....	541 749 39	300 000 00	142 016 00	4
9	28 689 83	25 351 84	....	1 179 881 61	....	9 645 904 60	1 180 000 00	97 910 85	3.5
10	....	5 423 72	....	13 732 92	....	462 022 46	287 000 00	....	3.75
11	2 862 21	7 699 86	16 083 92	175 156 45	....	....	....	....	.....
12	....	14 011 72	....	238 969 64	Forward.	2 216 155 38	1 250 000 00	393 903 48	3.56
13	51 529 13	37 138 53	....	88 667 66	City treasury.	1 235 558 46	569 000 00	146 646 48	.....
14	....	8 086 24	11 248 83	79 361 22	....	485 455 08	492 000 00	38 500 00	4.06
15	18 212 44	4 986 89	....	149 774 62	....	1 428 670 17	1 109 000 00	....	3½ and 4
16	2 757 20	49 322 18	....	189 183 09	General fund.	1 275 000 00	789 700 00	239 111 73	3½
17	....	27 077 19	....	145 663 35	....	1 484 271 75	961 000 00	387 126 98	4
18	....	21 295 39	....	139 174 82	....	1 283 527 77	350 000 00	128 652 09	.....
19	....	31 742 47	....	37 699 32	....	....	98 000 00	....	.....

20	....	14 086 92	....	149 773 97	....	2 232 208 52	712 000 00	54 674 45	4
23	17 655 83	1 006 64	....	230 518 15	Forward.	3 151 863 88	1 106 400 00	584 580 62	4
24	20 855 01	7 910 30	19 379 02	95 963 02	....	575 755 81	80 000 00	....	3¼
25	....	15 046 99	....	48 578 24	....	600 938 82	520 000 00	292 564 18	4
27	....	44 139 62	....	279 874 15	....	3 512 321 09	1 488 000 00	510 780 16	4.16
28	40 000 00	42 830 72	....	135 980 40	....	1 168 152 47	651 000 00	....	3.63
29	....	3 999 70[2]	....	....	City treasury.	2 355 135 64	1 375 000 00	605 568 62	4
30	....	3 296 11	....	52 366 18	Forward.	444 018 88	148 999 84	....	3.84
31	....	286 162 61	....	936 916 82	....	5 800 266 95	3 400 000 00	240 310 14	4.7
32	....	49 83	....	26 754 82	Forward.	318 576 06	189 000 00	....	4
33	4 088 12	45 366 68	220 948 02	716 619 24	Forward.	3 845 097 58	900 000 00	201 508 00	4
34	112 573 20[3]	62 128 24	....	238 191 02	City treasury.	922 834 26	56 000 00	....	4
35	36 638 87	159 991 49	195 606 30	1 778 945 32	Sinking fund.	4 157 214 57	2 095 000 00	175 000 00	3.7
37	....	[4]	856 13	109 377 31	Forward.[4]	1 391 656 65	860 500 00	398 890 49	3.96
39	10 32	10 655 88	....	63 611 72	....	529 873 81	296 000 00	....	3.85
40	5 461 11[1]	4 768 82	361 22	47 724 54	....	383 249 47	287 000 00	153 276 89	4
41	....	5 442 36	....	42 504 85	....	383 356 43	353 000 00	92 969 71	3.75
42	....	8 046 97	....	28 862 72	....	161 442 60	73 000 00	....	4
43	....	[4]	....	49 928 11	....	....	....	....	.....
44	....	....	96 063 54	124 933 03	....	52 749 65	....	....	.....

[1] To city treasury. [2] Deficit. [3] Metropolitan water assessment. [4] Maintenance balance to sinking fund.

1909. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number.	Name of city or town.	1	2	3	4	5	6	7	8	9	10	11	12
		Estimated population.						Average consumption. (Gallons per day.)				Cost of supplying water. Per million gals.	
		Total at date.	On line of pipe.	Supplied at date.	Total consumption for the year. (Gallons.)	Quantity used through meters. (Gallons.)	Percentage of consumption metered.	Total.	To each inhabitant.	To each consumer.	To each tap.	Figured on total maintenance. (Item CC.)	Figured on total maintenance + int'st on bonds.
1	Arlington, Mass.	11 500	10 600	10 500	309 762 205	107 491 602	35	848 417	74	81	418	. . .	. . .
2	Attleboro, Mass.	18 000	17 000	. . . .	301 612 468	. . . .	. .	826 336	45	48	. .	. . .	. . .
3	Billerica, Mass.	2 850	1 950	1 650	39 748 276	. . . .	. .	108 900	. .	66	. .	$73 87	$164 44
5	Brockton, Mass.	63 400[1]	61 700[1]	60 700[1]	830 926 082	600 241 222	72	2 276 510	36	37	289	51 16	127 87
6	Burlington, Vt.	21 500	21 000	20 900	364 864 341	228 682 273	63	999 628	46	48	259	61 54	85 22
7	Cambridge, Mass.	103 000	103 000	103 000	3 678 588 720	. . . .	. .	10 078 325	98	98	650	20 10	61 15
8	Chelsea, Mass.	35 475	35 475	35 475	1 047 331 000	461 040 000	44	3 316 900	81	81	. .	57 44	68 90
9	Detroit, Mich.	440 618	458 175	455 029	27 816 750 890	8 768 974 646	36	76 210 276	167	168	876	6 54	7 89
10	Dover, N. H.	15,000	14 000	13 500	272 805 000	67 985 634	40	745 556	49	55	342	44 13	79 80
11	East Orange, N. J.	35 000	34 800	34 750	1 091 201 300	99 733 600	9	2 985 130	89	90	454	41 94	74 79
12	Fall River, Mass.	115 097	. . . .	114 397	1 949 261 817	. . . .	. .	5 340 443	46	47	. .	. . .	. . .
13	Fitchburg, Mass.	. . . .	. . . .	. . . .	1 095 000 000	. . . .	. .	3 000 000	. .	86	. .	. . .	. . .
14	Framingham, Mass.	13 000	10 600	9 400	205 453 007	140 441 617	. .	562 885	43	60	350	62 64	153 22
15	Gloucester, Mass.	38 000	35 000	22 000[2]	502 204 723	79 930 650	16	1 375 903	48	55	313	44 39	125 94
16	Harrisburg, Pa.	70 000	69 000	70 000	3 658 543 100	2 744 277 500	75	10 023 406	143	143	645	13 46	21 71
17	Haverhill, Mass.	45 000	42 408	42 000	1 753 477 338	204 498 285	11	4 804 047	106	114	763	15 91	37 95
18	Holyoke, Mass.	54 698	54 488	54 011	2 046 592 000	653 290 500	. .	5 607 100	103	106	1 381	. . .	. . .
19	Keene, N. H.	11 000	10 000	9 000	. . . .	. . . .	. .	. . . .	. .	. .	. .	. . .	. . .
20	Lawrence, Mass.	82 000	. . . .	81 000	1 301 347 671	768 538 500	59	3 565 336	43	44	480	47 58	69 47
21	London, Ont.	50 000	. . . .	. . . .	. . . .	. . . .	. .	. . . .	. .	. .	. .	. . .	. . .
22	Louisville, Ky.	260 000	250 000	190 000	7 760 554 499	2 300 000 000	30	21 261 793	82	112	630	28 04	38 23
23	Lowell, Mass.	96 380	96 380	96 380	1 912 740 525	993 016 015	52	5 240 385	54	54	426	61 86	85 17
24	Madison, Wis.	29 906	. . . .	26 976	617 317 000	263 522 167	. .	1 691 279	56	65	. .	. . .	. . .
25	Marlboro, Mass.	14 200	14 000	13 800	208 933 300	96 187 500	41	572 420	40	41	245	48 81	148 37
26	Met. W. W., Mass.	965 490	. . . .	. . . .	43 575 790 000	. . . .	. .	119 386 000	124	. .	. .	. . .	. . .
27	New Bedford, Mass.	95 000	89 000	88 000	2 727 327 230	1 199 465 066	43	7 472 179	79	85	621	22 13	43 30
28	New London, Conn.	22 000	20 800	20 000	980 267 000	315 422 000	32	2 685 665	122	134	657	12 18	36 32
29	Newton, Mass.	39 750	39 400	39 200	855 802 436	562 000 000	66	2 344 664	59	60	292	. . .	. . .
30	Plymouth, Mass.	. . . .	. . . .	. . . .	462 482 000	114 605 000	25	1 267 000	. .	. .	. .	. . .	. . .
31	Portland, Ore.	275 000	196 700	196 700	. . . .	. . . .	. .	. . . .	. .	84	444	. . .	. . .
32	Reading, Mass.	5 760	5 685	5 300	67 920 004	42 083 496	62	186 082	32	351	138	117 54	229 82
33	Reading, Pa.	101 210	101 010	101 110	4 655 687 002	1 738 944 748	37	12 755 307	126	126	583	14 36	22 08

34	Somerville, Mass.	75 500	75 500	75 500	2 310 815 000	. . . .	. .	6 331 000	84	. .	. .	. . .	. . .
35	Springfield, Mass.	88 397	86 000	85 000	3 871 788 600	1 522 206 329	39	10 607 640	120	125	874	24 26	39 47
36	Sydney, C. B.	15 942	12 000	11 500	600 206 350	53 397 651	9	1 644 000	100	143	865	. . .	. . .
37	Taunton, Mass.	30 967	30 000	30 000	792 767 691	367 643 000	46	2 171 966	70	72	415	42 35	85 10
38	Ware, Mass.	9 000	8 900	8 850	158 447 880	106 246 386	68	434 103	48	50	499	. . .	. .
39	Watertown, Mass.	12 630	12 600	12 600	275 721 000	185 059 200	67	755 400	60	60	382	74 32	115 67
40	Wellesley, Mass.	7 035	6 975	6 935	118 198 000	67 725 000	53	324 000	46	47	284	. . .	. . .
41	Westerly, R. I.	13 500	12 000	11 000	246 059 400	. . . .	. .	647 135	50	61	391	44 22	98 56
42	Winchendon, Mass.	6 200	4 150	3 643	53 246 636	24 039 439	45	145 504	23	40	189	85 72	142 81
43	Woburn, Mass.	14 400	19 300	14 300	660 405 240	79 573 950	12	1 809 329	126	. .	. . .	. . .	. . .
44	Woonsocket, R. I.	35 809	40 548	40 048	537 866 481	406 857 523	76	1 473 607	36	37	443	33 75	. . .
45	Worcester, Mass.	146 417	144 417	144 417	3 238 662 500	2 265 052 985	70	8 873 048	61	62	385	24 49	68 68

[1] Including Whitman and Hanson.

[2] 12 000 extra during three summer months.

1909. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

Number.	Name of city or town.	1 Kind of pipe.	2 Sizes of pipes. (Inches.)	3 Length extended during the year. (Feet.)	4 Length discontinued during the year. (Feet.)	5 Total length in use. (Miles.)	6 Cost of repairs. (Per mile.)	7 Number of leaks. (Per mile.)	8 Length of pipe less than 4 in. diam. (Miles.)	9 Hydrants. Number added.	10 Hydrants. Total in use.	11 Gates. Number added.	12 Gates. Total in use.	13 Gates. No. smaller than 4-inch.	14 Gates. No. of blow-off gates.	15 Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	1 739	....	37	$1 40	....	0 8	4	384	3	319	...	...	50 & 90
2	Attleboro, Mass	C. I., W. I., Cem. L.	1–24	12 442	....	56	....	1	...	20	420	...	....	...	...	85–100
3	Billerica, Mass.	C. I.	6–12	3 746	....	10	....	4	...	5	108	...	84	...	4	54–120
4	Boston, Mass.	C. I., Cem. L.	2–48	63 327	20 781	761	366 66	72	2	104	8 331	152	10 153	18	396	35–90
5	Brockton, Mass.	C. I., Cem. L.	6–30	14 218	....	110	2 72	0 34	8 9	42	996	93	1 469	142	47	47–56
6	Burlington, Vt.	Cem. L., C. I., W. I.	4–30	3 361	0	41	....	....	5	7	236	3	684	75	16	70–85
7	Cambridge, Mass.	C. I.	2–40	6 138	....	131	....	19	2	15	1 071	66	....	0	...	55–60
8	Chelsea, Mass.	C. I.	2–16	197	....	42	....	....	01	4	333	3	462	1	50	50–75
9	Detroit, Mich.	C. I.	2–48	154 039	25 665	752	2 54	0 13	10	396	5 243	352	7 954	21	961	8–62
10	Dover, N. H.	C. I.	3–16	2 976	0	27	....	....	2	...	189	3	264	0	8	68–114
11	East Orange, N. J.	C. I., W. I.	2–24	15 255	....	84	....	....	0 3	50	594	135	1 288	5	10	55–115
12	Fall River, Mass.	C. I.	6–24	......	....	110	....	....	.....	41	1 278	42	1 310	...	...	80
13	Fitchburg, Mass.	C. I., W. I., Cem. L.	2–30	7 314	....	76	....	....	.....	19	631	22	708	...	...	86 & 165
14	Framingham, Mass.	C. I., W. I.	1–16	21 441	0	36	....	....	4	22	203	34	431	48	39	60–106
15	Gloucester, Mass.	C. I., Cem. L.	1–20	7 633	....	66	21 49	0 96	22	8	317	15	533	169	27	15–75
16	Harrisburg, Pa.	C. I.	6–42	16 835	....	67	....	3	.....	33	867	61	1 613	...	8	30–70
17	Haverhill, Mass.	C. I., Cem. L.	2–24	18 064	....	91	....	....	.....	2	361	53	1 025	...	...	30–120
18	Holyoke, Mass.	W. I., C. I., Ld. L.	½–30	4 332	2 46	91	8 58	8	6	4	946	31	993	20	42	60–100
19	Keene, N. H.	W. I., Cem. L., C. I.	4–24	3 454	736	41	....	....	3	4	261	3	400	...	31	50–65
20	Lawrence, Mass.	C. I.	1–30	13 369	1 758	95	0	0	8	27	756	83	1 426	0	...	65–125
21	London, Ont.	C. I.	2–20	7 466	1 038	98	..	0 06	5	17	619	25	643	16	5	40–90
22	Louisville, Ky.	C. I.	3–48	99 487	3 348	338	41 46	1 7	2	96	958	164	5 062	176	28	40–75
23	Lowell, Mass.	C. I.	4–30	9 965	....	143	2	....	.....	15	1 321	49	1 558	31	34	17–72
24	Madison, Wis.	C. I.	3–16	34 188	....	59	....	....	.....	40	350	79	487	...	3	53–65
25	Marlboro, Mass.	C. I.	4–16	0	0	37	0 79	0 11	0 89	0	354	0	394	19	65	35–142
26	Met. W. W., Mass.	C. I., Cem. L.	6–60	7 88[1]	....	92	....	....	.....	...	....	32	404	...	...	.....
	Met. Water Dist. (total in district supplied)	C. I., Cem. L., Kal.	4–60	33 77[1]	....	1 603	....	....	.....	276	14 355	...	....	...	...	.....
27	New Bedford, Mass.	C. I.	4–36	24 105	3 512	118	12 88	0 10	0 8	57	1 239	78	1 472	110	104	25–95
28	New London, Conn.	Cem. L., C. I.	4–24	2 293	0	69	5 76	0 3	4	7	370	12	535	...	41	45–70
29	Newton, Mass.	C. I.	4–20	6 422	0	145	1 40	1 4	3 5	9	996	12	867	53	429	80–86

30	Plymouth, Mass. . . .	Cem. L., W. I.	2–20	12 807	10 478	52	12 43	0 96	10	10	258	44	586	141	41	. . . . . .
31	Portland, Ore.	C. I., Steel, Wood.	2–30	55 477	12 700	324	. . . .	. . . .	63	. . .	. . . .	194	2 316	311	138	20–80
32	Reading, Mass.	C. I.	6–12	5 740	. . . .	31	1 04	0	. . .	11	179	10	280	. . .	14	63–78
33	Reading, Pa.	C. I.	2–36	6 758	1 508	114	19 72	0 61	04	7	965	26	2 905	4	(2)	10–133
34	Somerville, Mass. . . .	C. I.	4–20	7 114	. . . .	94	. . . .	0 12	. . .	18	1 103	32	1 454	. . .	141	35–100
35	Springfield, Mass. . . .	Cem. L., W. I., C. I.	1–54	104 782	35 998	175	5 98	0 18	6 44	40	1 367	301	3 240	553	92	30–135
36	Sydney, C. B.	C. I.	4–24	4 130	. . . .	27	5 59	0 48	0 16	. . .	148	12	210	2	17	68–87
37	Taunton, Mass.	C. I.	4–20	6 219	0	86	28 11	0 20	1 5	15	965	19	666	12	63	50–120
38	Ware, Mass.	C. I.	4–12	. . . . .	. . . .	13	. . . .	. . . .	1 9	. . .	125	1	134	15	3	90–95
39	Watertown, Mass. .	C. I., Cem. L.	4–16	3 719	. . . .	38	1 04	. . . .	6	3	338	5	440	49	13	40–100
40	Wellesley, Mass.	C. I., Cem. L.	1½–12	4 371	0	37	0 66	0 60	1	5	331	6	278	10	3	35–125
41	Westerly, R. I.	C. I.	4–16	1 498	0	35	. . . .	0 17	. . . . .	1	167	2	220	4	. . .	40–92
42	Winchendon, Mass. .	C. I., W. I.	2–14	7 693	0	23	. . . .	. . . .	2 5	11	165	6	212	37	17	40–163
43	Woburn, Mass.	C. I., Cem. L.	4–14	1 172	. . . .	57	35 24	2 12	6	2	382	9	455	55	17	70–75
44	Woonsocket, R. I. . . .	C. I.	4–20	6 724	0	56	0 29	0 03	0	10	648	12	589	0	16	50–120
45	Worcester, Mass. . .	. . . .	2–40	10 85[1]	. . . .	220	. . . .	. . . .	. . . . .	62	2 150	54	3 094	. . .	. . .	70–150

[1] Miles.

[2] Included in items 12 and 13.

[3] Includes hydrants.

1909. — TABLE 5. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — SERVICE PIPES.

Number.	Name of city or town.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		SERVICE PIPE.					SERVICE TAPS.		Average length of services. (Ft.)	Average cost of services for the year.	METERS.		Percentage of services metered.	Percentage of receipts from metered water. (B) ÷ (C)	MOTORS & ELEVATORS.	
		Kind.	Sizes. (Inches.)	Extended. (Feet.)	Discontinued. (Feet.)	Total in use. (Miles.)	Number added.	Total in use.			Number added.	Now in use.			Added.	Total in use.
1	Arlington, Mass. . .	C. I., Galv. I., Cem. Lined.	$\frac{5}{8}$–6	. . . .	. . .	. .	77	2 032	. .	$17 26	129	1 121	55	62	. .	4
2	Attleboro, Mass. . .	. . . .	. .	. . .	. . .	. .	. . .	2 234	. .	. . . .	145	2 246	. . .	. . . .	. .	2
3	Billerica, Mass. . . .	W. I., Cem. Lined.	1–1$\frac{1}{2}$	1 458	. . .	4	18	312	72	. . . .	17	197	63	73	. .	. . .
4	Boston, Mass.	Lead, Lead Lined Iron., C. I.	$\frac{1}{2}$–16	31 608	4 983	533	1 149	96 194	29	0 25	6 669	12 049	12	48	0	700
5	Brockton, Mass. . .	W. I., Ld. Lnd., Cem. Lnd., C. I.	$\frac{3}{4}$–8	8 041	626	56	375	7 879	47	17 54	340	7 817	99	99	. .	15
									20	10 09						
6	Burlington, Vt. . . .	Galv., C. I., Lead.	$\frac{1}{2}$–6	1 327	329	21	46	3 846	30	14 43	79	3 279	85	88	0	42
7	Cambridge, Mass. .	Galv., C.I., Tin Lnd., Lead Lnd.	$\frac{3}{4}$–8	6 090	. . .	. .	156	15 492	39	21 13	365	4 278	27	. . . .	. .	. . .
8	Chelsea, Mass.	Lead.	$\frac{5}{8}$–2	3 007	. . .	34	99	4 601	30	14 61	855	2 210	48	65	0	3
9	Detroit, Mich.	Lead, C. I., Galv.	$\frac{5}{8}$–10	. . . .	. . .	. .	3 683	86 649	. .	. . . .	509	7 956	9	. . . .	0	36
10	Dover, N. H.	C. I., Cem. Lined.	1–8	1 604	0	18	27	1 884	43	. . . .	104	1 004	53	58	0	9
11	East Orange N. J. .	Lead, W. I., C. I.	$\frac{1}{2}$–6	24 750	. . .	77	495	6 828	60	29 15	80	679	10	18	0	4
12	Fall River, Mass. .	Lead.	$\frac{1}{2}$–2	. . . . .	. . .	. .	217	8 316	. .	. . . .	236	8 197	. . .	. . . .	. .	. . .
13	Fitchburg, Mass. . .	W. I., Cem. Lined, C. I.	$\frac{3}{4}$–8	. . . . .	. . .	. .	113	5 067	. .	. . . .	121	3 504	. . .	. . . .	6	128
14	Framingham, Mass.	Lead, W. I., Galv., C. I.	$\frac{1}{2}$–8	6 578	. . .	. .	102	1 608	64	15 70	445	1 594	. . .	. . . .	. .	. . .
15	Gloucester, Mass. .	Cem. Lined, Galv.	1–6	3 059	0	17	152	4 390	21	32 97	13	237	5	16	. .	. . .
16	Harrisburg, Pa. . . .	Lead, Galv.	$\frac{1}{2}$–8	. . . .	. . .	. .	571	15 528	. .	. . . .	515	9 432	78	81	. .	27
17	Haverhill, Mass. . .	Lead, W. I.	$\frac{1}{2}$–4	10 267	266	49	192	6 294	48	22 96	125	974	15	28	. .	20
18	Holyoke, Mass. . . .	Cem. Lnd., Rub. Lnd., Enam., Ld. Lnd., Tin Lnd., Galv.	$\frac{1}{2}$–6	1 401	5	16	89	4 061	20	16 89	25	351	. . .	. . . .	. .	157
19	Keene, N. H.	W. I., Lead, Galv.	$\frac{3}{4}$–6	720	. . .	12	24	1 996	. .	. . . .	17	154	. . .	. . . .	0	16
20	Lawrence, Mass. . .	Galv. Lead, C. I., Lead Lined.	$\frac{3}{4}$–10	14 681	972	59	340	7 416	42	21 89	269	6 633	90	94	. .	19
21	London, Ont.	Lead.	$\frac{1}{2}$	. . . .	. . .	. .	363	12 332	60	15 88	236	613	2	. . . .	. .	. . .
22	Louisville, Ky.	Lead and Iron.	$\frac{5}{8}$–6	. . . .	. . .	. .	1 433	33 731	30	12 73	244	2 642	8	43	. .	. . .
23	Lowell, Mass.	Lead, Ld. Lnd., Tin Lnd., W. I.	$\frac{5}{8}$–2	7 046	. .	92	190	12 307	37	27 56	328	9 465	77	87	. .	. . .
24	Madison, Wis.	Lead.	$\frac{5}{8}$–1$\frac{1}{2}$	5 886	. . .	23	236	4 647	. .	. . . .	236	4 577	99	. . . .	. .	. . .
25	Marlboro, Mass. . . .	Cem. Lnd., Ld. Lnd., Lead, Galv.	$\frac{3}{4}$–2	881	0	10	33	2 336	27	15 46	53	1 557	67	73	0	19
26	Met. Water Dist. . .	. . . .	. .	. . . .	. . .	. .	2 863	158 200	. .	. . . .	12 381	44 855	. . .	. . . .	. .	. . .
27	New Bedford, Mass.	Lead, C. I., W. I.	$\frac{1}{2}$–10	22 406	3 451	81	527	12 043	35	21 39	944	4 572	38	65	12[1]	172
28	New London, Conn.	Cem. Lined, Galv., Lead.	$\frac{1}{2}$–4	1 174	425	13	67	4 086	17	13 20	78	645	16	. . . .	0	2
29	Newton, Mass.	Galv., Tarred I., Lead.	$\frac{3}{4}$–6	18 253	8 239	91	133	8 033	75	27 00	245	7 037	88	99	0	18
30	Plymouth, Mass. . .	Lead, Cem. Lined.	$\frac{1}{2}$–4	635	. . .	7	55	2 415	12	8 18	. . . .	89	4	. . . .	0	1

31	Portland, Ore.....	Galv.	..	....	...	..	3 978	37 120	..	....	6 332	12 617	34	....	..	...
32	Reading, Mass....	C. I., Lead, Cem. Lined.	¾–6	3 407	378	19	34	1 344	87	78 36	51	1 242	..	....	..	..
33	Reading, Pa......	Lead, W. I., C. I., Lead Lined.	½–8	....	...	..	350	21 883 [2]	..	....	450	3 020	14	31	142	273
34	Somerville, Mass. .	Lead, Ld.Lnd.,Cem. Lnd., C. I.	½–6	3 016	...	78	211	12 018	..	20 28	870	5 155	43	49	0	8
35	Springfield, Mass..	Lead, Cem. Lnd.,Tarred, Galv., C. I.	½–8	....	...	..	428	12 134	..	....	600	7 017	58	66	17	337
36	Sydney, Ont......	Lead, Galv., C. I.	½–6	2 780	...	9	93	1 900	30	13 79	1	23	1	16	..	8
37	Taunton, Mass....	Cem. Lined, Tin Lined.	¾–4	5 949	0	51	114	5 237	..	....	122	2 630	50	71	0	21
38	Ware, Mass.......	W. I., Cem. Lined.	1–2	622	...	10	10	870	62	....	18	884	93	....	..	12
39	Watertown, Mass..	W. I., Cem. Lnd. and Galv.	1–2	2 349	...	19	54	1 973	43	54 56	59	1 993	100	100	..	...
40	Wellesley, Mass...	C. I., Cem. Lnd., W. I., Lead, Ld. Lined.	½–8	4 886	233	22	61	1 140	75	9 46	....	....	100	....	..	...
41	Westerly, R. I.....	Lead, Iron.	½–6	2 139	0	..	37	1 724	10	18 66	37	1 466	85	....	0	12
42	Winchendon, Mass.	W. I., Cem. Lined.	1–2	2 710	0	7	55	770	49	6 60	55	770	96	99	0	1
43	Woburn, Mass....	Lead Lined, Cem. Lnd., Galv.	1	....	...	..	39	3 222	..	30 39	12	87	3	23	..	10
44	Woonsocket, R. I.	Lead, C. I.	⅝ 8	2 443	0	9	186	3 326	14	11 05	160	2 878	86	97	0	17
45	Worcester, Mass...	....	..	....	...	15	507	....	..	....	490	15 599	..	....	..	...

[1] Deducted.

[2] Estimated.

DEPRECIATION, — IN WATER-WORKS OPERATION AND ACCOUNTING.

BY LEONARD METCALF.*

[Read September 22, 1910.]

That the author may not hereafter be charged with plagiarism he calls attention to the fact that a portion of this paper was written by him early in the year 1910, for insertion in a report (made by Mr. John W. Alvord, of Chicago, and the writer) upon the reproduction cost of the water works supplying one of the larger cities of the United States. It was subsequently used, in part, by Mr. Alvord (as stated by him at the New Orleans Convention of the American Water Works Association, held in April, 1910) as a basis for the progress report to that association of the "Committee upon Depreciation," of which he was the chairman and the writer was a member. The water company officials have courteously consented to the use of the material submitted to them, and it was thought that the fact that some of the opinions expressed had been reported to an operating company, as suggestions bearing upon its future government, might give it an added interest.

DEPRECIATION.

The fact that structures deteriorate with age and through other causes is well known to owners of property. Nevertheless, substantial recognition has not generally been given to this fact in the operation of water works, by providing a depreciation fund or account, to be earned by the rates, against which fund the cost of all abandoned structures and replacements should be charged. The decision of the Supreme Court of the United States upon the Knoxville Water Works case, delivered by Mr. Justice Moody,†

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† Thus Mr. Justice Moody says: "The company is not bound to see its property waste without making provision out of its earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that at the end of any given term of years the original investment remains as it was at the beginning. It is not only the right of the company to make such a provision, but it is its duty to its bond and stock holders, and, in the case of a public-service corporation at least, its plain duty to the public. If, however,

and handed down in January, 1909, gives emphasis to the need of practical recognition of depreciation by managers of public-service corporations, and will effectually estop hereafter any corporation from making claim for the effect of depreciation of its property that has failed to earn, through the agency of its rate, a sufficient fund to meet this depreciation.

Exception might be made in the plants which have not yet passed through the formative period, or which, by reason of heavy reconstruction expenses, have not been able to lay aside a suitable depreciation fund without increasing the rates. Such plants may have preferred to temporarily suspend the laying aside of a depreciation allowance, in the hope of making good the deficit a few years later, rather than to bear the public odium of temporary increase in rates. It seems reasonable to assume that a public-service commission would take the same view.

Without attempting a lengthy discussion of this subject, it may lead to clearness and be of service to lay down some of the principles which should govern us in making depreciation allowances in valuation, and which should have influence in the operation of a water-works plant.

DEFINITION AND KINDS OF DEPRECIATION.

Depreciation may be defined as the loss in value of a structure, resulting from wear and tear and other causes not covered by the repair and renewal accounts, or from loss in ability, with the lapse of time, to meet the demands of the service for which it was designed or to which it is being devoted.

Three broad classes of depreciation have been recognized:

1. Physical depreciation.
2. Functional depreciation.
3. Contingent depreciation.

Physical depreciation covers the deterioration of the structure through wear and tear, or similar causes, which result in its actual

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a company fails to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over-issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purposes of earning a return cannot be enhanced by a consideration of the errors which have been committed in the past."

gradual inability to meet the required service, in spite of repairs and renewals from time to time.

Functional depreciation covers the loss in value, growing out of the necessity of abandoning the structure, on account of obsolescence, change in methods of operation, improvement of the art, increase in capacity of plant, or other similar causes.

Contingent depreciation should cover such loss in value of the structure as cannot logically be included in the other two items, and as shall make possible the gradual distribution, through a period of years, of any extraordinary depreciation item incurred in a single year, and thus have a steadying influence upon the financial operations of the company, relieving it of the burdens incident to the violent fluctuations in value which might result were such items charged directly to maintenance account. It is to be assumed, of course, that these items are properly chargeable to depreciation or maintenance, to the end that the capital investment may be unimpaired. Under this classification contingent depreciation may include such work as the cost of relocating the street mains, growing out of changes in grade or surface of the street by the municipality, the construction of subway or conduit systems by the municipality (in the case of telephone companies the placing of wires underground which had previously been overhead), and finally, as a matter of expediency, such major expenses as might otherwise be charged to maintenance account, — such as those growing out of serious losses from damage done by bursting mains, due to unforeseen and reasonably unpreventable conditions, — such as flaws in the material which cannot be determined by inspection; electrolysis by stray electric currents, et cetera. While it may be urged that such expenses should be charged to operation, — or better, maintenance, — we submit that such a course of procedure does injustice to the company through causing a false impression as to its financial ability to meet the losses, by seriously curtailing the annual earnings for the year during which the loss was incurred, when the distribution of the losses over a period of years, through the agency of such a contingent depreciation account, would show no marked affect upon the earnings and annual statement of the company. While, so far as the writer knows, this question has not been brought before the public

service commissions or the courts for adjudication, it seems probable that its soundness will be recognized by them and by all fair-minded men who have had business experience or experience in the operation of such works.

DIFFICULTIES OF OBTAINING RECORDS OF ACTUAL DEPRECIATION.

Specific information as to actual rates of depreciation is unfortunately limited, and attention is particularly called to a very common error in the interpretation of such data as are available, which a moment's reflection will make clear. From time to time, data have been published as to the length of life of certain engineering structures, — such, for instance, as pumps, — and it has been inferred from these data that the length of life of the average pump might be predicated directly upon them. Unfortunately, however, the data usually do not include a full history of the plants under investigation, but merely a record of the machines which have actually been thrown out of service, without consideration of the machines which are still in useful service. The effect of this is to substantially decrease the assumed period of useful life of the machine. Fortunately for the property holder, this error leads to a conservative assumption as to the period of useful life. Under these circumstances, it is clear that only breadth of experience with specific plants, or study of the actual experience of these plants, can develop competent judgment.

The actual rate of depreciation, in any given structure, may be exceedingly erratic. Take, for instance, the case of a pump in a water-works pumping station. A year after the new machine is installed, it is a better machine for the service than it was upon the day of its erection, for the reason that not only have flaws in construction been made good, but the actual wearing parts of the machine have come down to a good bearing, so that the machine, as a whole, operates with better economy than at the beginning of its life. The pump may continue to be substantially as valuable to the works for a considerable period of years, until it is outgrown in size and a new machine has to be added to take care of the increased service. This pump then becomes a spare machine, operated only at times of light load, and has suffered a marked depreciation in value because it will not meet all of the demands

of the service successfully, although it may assist in increasing the economy of operation of the station by making possible the shutting down of the new large or larger unit which had to be purchased, when the consumption is not sufficient to develop good economy in the large machine. The old pump may continue in service for many years, reaching a period when it is so small as to be of value only as one of several spare machines, when its value is very heavily depreciated.

It will thus be seen that it is practically impossible, as an accounting problem, to attempt to follow the life-history of the individual machines or structures making up the water-works plant, and, as a practical matter, it is sufficient if there is laid aside, annually, from the income from the rates, a fund which will make good, from year to year, the losses by depreciation, or which will, in other words, replace the old structures, as put out of service, without injury to the capital account. If the assumption as to the life of the plant as a whole is substantially correct, errors in assumption as to the useful life of its component parts are not so serious, though substantial accuracy is desirable for its effect upon rate making problems or considerations.

METHODS OF COMPUTING DEPRECIATION FUND.

Granting that the water works should lay aside an annual depreciation account which, with or without its accretions, — depending upon the method of raising and maintaining this fund, — will be sufficient to maintain in the hands of the corporation monies which will enable it to replace each component part of the plant at the end of its useful life, thus maintaining the investment unimpaired, "What method is the most satisfactory for accomplishing this end, — that is, for determining the annual sum which shall be contributed to the depreciation fund?"

Two general methods are in common use, — the so-called "sinking fund" method and the "straight line" method.

The *sinking-fund method,* as its name implies, consists in laying aside each year, during the period of life of the structure under question, a sum which with its annual accretions, compounded annually at an assumed rate of interest, will leave in hand, at the end of the useful life of the structure, a sum equal to its original cost less its scrap value.

Owing to the fact that the scrap value of the structure frequently is little more than sufficient to cover the cost of its removal, and that, in the case of a long-lived structure, the present worth of the scrap value would be exceedingly small, engineers have generally omitted the correction for the scrap value of the structure and have assumed, unless the life of the structure was comparatively short, that the scrap value was negligible. In the case of very short-lived structures, it is better that the cost of the structure should be charged off to operating expense, rather than to capital account with large annual allowance for depreciation.

The *straight-line method* consists in laying aside an annual sum proportioned to the length of useful life of the structure. Thus, if the life of the structure be assumed at 30 years, one thirtieth of the difference between the original cost of the structure and its final scrap value shall be contributed to the depreciation fund during the entire life of the structure. The corporation will thus have in hand, at the end of the 30-year period of life, a sum of money equal to the original cost of the structure.

Mention might also be made of what might be termed "the individual analysis method of computing depreciation," for use in cases where unusual local conditions or temporary circumstances might be dominating factors. As this method is rather in the nature of a modification of the other methods cited than a specific method of computing depreciation, no further comment is needed upon it.

Difference between These Methods.

The essential differences between these two methods of meeting the needs of the depreciation account are:

First, the fact that the *sinking-fund method* requires not only an annual contribution to the principal sum of the depreciation account, but that care be observed in the method of accounting for this fund, to the end that it may receive annual accretions of interest, which accretions with the principal sum and contributions will receive annual interest, so that the fund may, in fact, be a true sinking fund and enjoy the compounding effect of the interest allowances.

In the case of the *straight-line method*, no accretions or interest

allowances are credited to the fund, — the principal sum of the annual deposits being sufficient alone to make up the necessary depreciation fund at the end of the useful life of the structure. Such earnings, therefore, as may be enjoyed upon the straight-line depreciation account should be credited to the general operation of the works and not to the depreciation account itself, whereas the reverse is the case in the sinking fund method of application.

Second, and of perhaps greater importance to the operator of water works, — particularly of new works, — the sinking-fund method requires much smaller annual contributions to the depreciation account, and the accretions thereon amount to a much smaller sum, during the early years of the life of the plant, whereas in the later years the accretions become a very important element, rapidly swelling the amount of the fund. It will thus be seen that the works are relieved by this method, in the early years of the formative period, from a burden which might prove heavy for the corporation and the water takers to bear under the straight-line method.

CORRECTION OF ERRORS IN ASSUMPTION AS TO DEPRECIATION.

What, it may be asked, will be the result of errors in judgment in the determination of the useful life of the component parts of water works?

If the assumption as to this length of life is too great, obviously the depreciation fund will dwindle, and it will be necessary for the corporation to gradually increase the annual contributions until the fund is again in a normal condition. If, on the other hand, the assumption has been too large, the depreciation account will grow at too rapid a rate, when the annual rate of contribution should be somewhat reduced. It should be noted, however, that the life of any one, or, indeed, the life of several component parts of the structure, must not be taken as indicative of the assumptions as a whole, for the reason that we must, of necessity, deal with average rather than individual results. If, on the other hand, the structure under consideration is one of large value, and the assumptions have been erroneous, steps might well be taken to correct the error as soon as possible. Thus, if the life of a large and expensive pump should prove to be but three fourths of the assumed

life, and the straight-line method of depreciation fund contributions had been assumed, there would be in the hands of the corporation, at the end of the life of this pump, but three fourths of the original cost of the pump. The capital would thus be impaired to the extent of 25 per cent. of the cost of this machine, unless the difference be made good from the depreciation fund and steps be taken to increase the annual contributions thereto to offset this original error in assumption. As to the useful life of the pump, if we grant that the management used reasonable judgment in the purchase of this machine, the investor is entitled to have his capital kept inviolate, or unimpaired, even though the machine fail to serve its intended purpose for as long a number of years as expected.

REASONABLE ASSUMPTIONS AS TO PERIOD OF USEFUL LIFE OF STRUCTURE.

All of these methods are but aids to judgment. They must be applied with care and discretion, and with a clear conception of the extent and effect of the local influences or considerations. No subject in the engineering field requires larger experience or riper judgment.

While general limits for depreciation in water-works property, found under what might be considered normal conditions, may be indicated and are submitted herein, the fact that local conditions and limitations are likely to have substantial influence upon current depreciation in any specific plant must never be lost sight of.

In determining what constitutes a reasonable annual allowance for depreciation in the operation of any water works, we are dealing with conditions yet to be developed, requiring foresight as well as "hindsight." Hence the hazards and penalties of errors in judgment must be weighed.

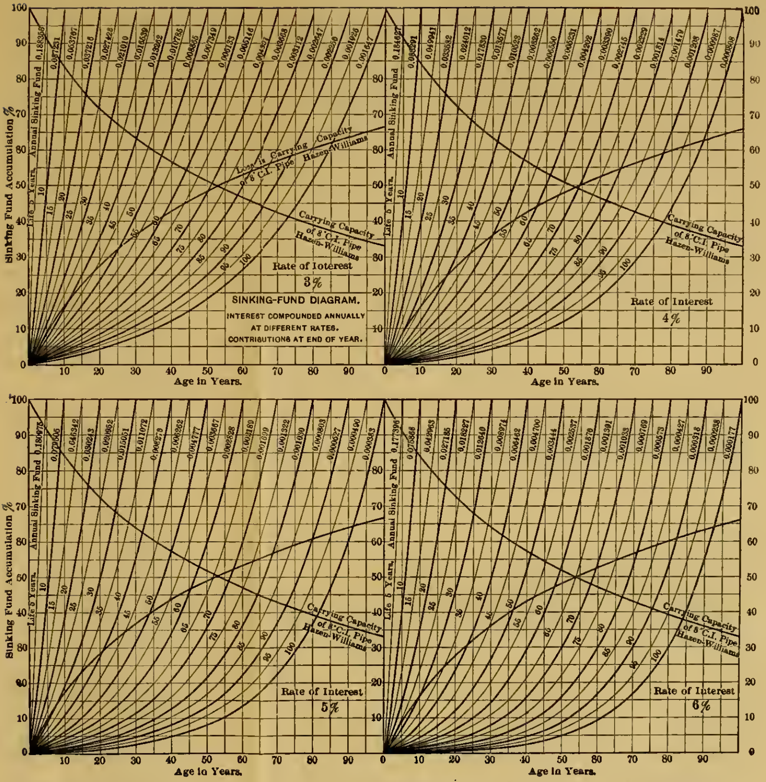
Final analysis of the necessary amount of or contributions to depreciation fund ultimately resolves itself into a question of expediency and standards of the day. It is well to be conservative in forecasting the annual needs for depreciation, alike in the interest of the public and of the corporation whose funds are invested in the plant; for it is easy to charge off or make future abatement for an excessive amount earned by the rates and credited to de-

preciation account, while it may be difficult later to recover, by increased depreciation allowances, earlier deficits caused by failure to make adequate allowance therefor. In the long run, failure to make ample provision for depreciation, either through failure to earn it by the rates or to retain it in the treasury for legitimate corporate use (not for disbursement in dividends), must inevitably upon the one hand make capital apprehensive of the soundness of the management, if not of the project itself (and thus lead to demands for higher returns commensurate with the added risk, or to flat refusal to go into the project), and, upon the other, force the public to meet this demand by the payment of higher rates than would otherwise be necessary for the service rendered.

Cases sometimes arise in which the income of the water works may not at the moment justify what appears to be an adequate provision for possible or anticipated depreciation, and in which questions of expediency — growing out of the desire to avoid the public agitation and odium which would follow an attempt to increase rates for this reason — may make it preferable to take the chances of making good present deficiencies in depreciation account by future increments, rather than to raise the water rates temporarily. Such action may be justified *provided* the past financial history of the works indicates clearly that the growing net income will, with continuity of the existing water rates, in the *near* future produce a surplus which will wipe out this deficiency. This is particularly true of the allowance to be made for "contingent depreciation."

This condition corresponds to that of what might be termed the judiciously "over-built plant," which is at the end of a reformative period, so far as construction or reconstruction of the plant (that is, the physical plant) is concerned, and at the beginning of a recuperative period so far as the financial condition of the plant is concerned.

Similarly, it may be good judgment, if the water works have had an abnormally good business year, yielding an unexpectedly large net income, to credit a portion of this excess profit to depreciation account or to the amortization of the water-works debt, for the relief of subsequent bad years, as would be done under similar circumstances by the prudent manufacturer in running his busi-



Furnished through the courtesy of the American Society of Civil Engineers, from Vol. LXIV, Metcalf on Water-Works Valuation.

ness. Nevertheless, Justice Moody's words, in his opinion in the Knoxville Water Company case, handed down by the United States Supreme Court in January, 1909, leave little room for the exercise of judgment in this annual provision of the necessary depreciation account allowances.

In the case of water-works valuation, the difficulty of determining the *accrued* depreciation, while substantial, is not so serious as is the difficulty of closely forecasting the *future* depreciation alluded to above.

Subject to the words of caution referred to above, the following approximate figures bearing upon the life of different structures entering into a water-works plant are given, as representing the general range ascribed to them by competent engineers testifying in water-works valuation suits. Knowing the period of useful life of a structure, the annual depreciation may be found by whatever method best fits the case. It will be well, however, to bear in mind the method to be used in figuring the depreciation, when estimating the probable life of the structure, if safe or conservative results are desired, — particularly if the sinking-fund method of computation is to be adopted and a high rate of interest is to be used in figuring the accretions upon the fund.

The following diagrams — Plate I based upon the sinking fund method and rates of interest of 3 per cent., 4 per cent., 5 per cent., and 6 per cent., and Fig. 1, based upon the sinking-fund method and rates of interest varying from $2\frac{1}{2}$ per cent. to 4 per cent., dependent upon the assumed length of life — will be found of service for rapid approximate computation or estimating purposes. Tables 2 and 3 also give similar data with greater precision. More complete information can be had from the "Robinsonian Bond and Investment Tables," published by J. Watts Robinson.

Data concerning formulæ for the computation of sinking funds, etc., are to be found in a paper presented by the writer before the American Society of Civil Engineers upon "Water-Works Valuation and Fair Rates," published in the Transactions of the Am. Soc. C. E., Vol. LXIV, 1909, pages 20 to 24.

An interesting article upon depreciation of contractor's plant was published in the issue of July 15, 1908, of *Engineering-Contracting*, in which are quoted the allowances made by MacArthur

Brothers' Company for depreciation upon their plant used in the construction of the Cross River dam for the Aqueduct Commission of New York City, the stated depreciations being monthly

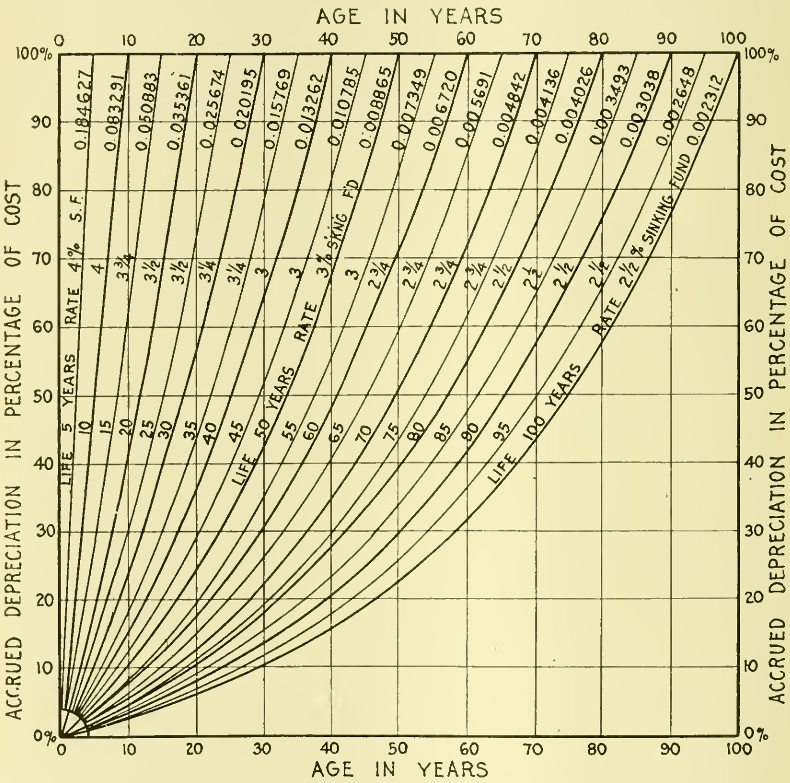


FIG. 1.

DEPRECIATION. DIAGRAM BASED ON SINKING FUND METHOD, WITH INTEREST RATES VARYING FROM 2½ PER CENT. TO 4 PER CENT., ACCORDING TO ASSUMED LIFE OF STRUCTURE. COMPOUNDED ANNUALLY, CONTRIBUTIONS AT END OF YEAR.

allowances. These data are submitted in Table 4, with a memorandum of the corresponding length of life, by the straight-line depreciation formula, and by the sinking-fund method, with 5 per cent. rate compounded semi-annually.

TABLE 1.

Approximate Life and Corresponding Annual Contributions to Sinking Fund.

Water-Works Structures.	General Limits of Useful Life. Years.	Corresponding Annual Contribution to Depreciation Account at End of Year in Per Centum of Cost of Structure,* based upon				
		Sinking-Fund Method, using Interest Rate Compounded Annually at				Straight-Line Method.
		5 Per Cent.	4 Per Cent.	3 Per Cent.	$2\frac{1}{2}$ Per Cent. to 4 Per Cent., Depending upon Length of Life.	
Reservoirs	50–100	$\frac{1}{2}\%-0\%$ †	$\frac{5}{8}\%-\frac{1}{8}\%$	$\frac{7}{8}\%-\frac{1}{8}\%$	0.89–0.23	$2\%-1\%$
Steel Standpipes	25–40	$2\frac{1}{8}\%-\frac{3}{4}\%$	$2\frac{3}{8}\%-1\%$	$2\frac{3}{4}\%-1\frac{3}{8}\%$	2.57–1.33	$4\%-2\frac{1}{2}\%$
Masonry Buildings	30–50	$1\frac{1}{2}\%-\frac{1}{2}\%$	$1\frac{3}{4}\%-\frac{5}{8}\%$	$2\frac{1}{8}\%-\frac{7}{8}\%$	2.02–0.89	$3\frac{1}{3}\%-2\%$
Wooden Buildings	20–40	$3\%-\frac{3}{4}\%$	$3\frac{3}{8}\%-1\%$	$3\frac{3}{4}\%-1\frac{3}{8}\%$	3.54–1.33	$5\%-2\frac{1}{2}\%$
Filter Plants, Permanent Construction	25–50	$2\frac{1}{8}\%-\frac{1}{2}\%$	$2\frac{3}{8}\%-\frac{5}{8}\%$	$2\frac{3}{4}\%-\frac{7}{8}\%$	2.57–0.89	$4\%-2\%$
Pumping Machinery, High Duty in large units	30–50	$1\frac{1}{2}\%-\frac{1}{2}\%$	$1\frac{3}{4}\%-\frac{5}{8}\%$	$2\frac{1}{8}\%-\frac{7}{8}\%$	2.02–0.89	$3\frac{1}{3}\%-2\%$
Ordinary Pumping Machinery	20–30	$3\%-1\frac{1}{2}\%$	$3\frac{3}{8}\%-1\frac{3}{4}\%$	$3\frac{3}{4}\%-2\frac{1}{8}\%$	3.54–2.02	$5\%-3\frac{1}{3}\%$
Steam Engines	15–25	$4\frac{5}{8}\%-2\frac{1}{8}\%$	$5\%-2\frac{3}{8}\%$	$5\frac{3}{8}\%-2\frac{3}{4}\%$	5.09–2.57	$6\frac{2}{3}\%-4\%$
Boilers	12–20	$6\frac{1}{4}\%-3\%$	$6\frac{5}{8}\%-3\frac{3}{8}\%$	$7\%-3\frac{3}{4}\%$	6.66–3.54	$8\frac{1}{3}\%-5\%$
Electric Generators and Motors	20–30	$3\%-1\frac{1}{2}\%$	$3\frac{3}{8}\%-1\frac{3}{4}\%$	$3\frac{3}{4}\%-2\frac{1}{8}\%$	3.54–2.02	$5\%-3\frac{1}{3}\%$
Masonry Conduits	50–100	$\frac{1}{2}\%-0\%$ †	$\frac{5}{8}\%-\frac{1}{8}\%$	$\frac{7}{8}\%-\frac{1}{8}\%$	0.89–0.23	$2\%-1\%$
Cast-Iron Pipe, large diameter.						
In Non-Tuberculating Waters	60–100	$\frac{1}{4}\%-0\%$ †	$\frac{3}{8}\%-\frac{1}{8}\%$	$\frac{5}{8}\%-\frac{1}{8}\%$	0.67–0.23	$1\frac{2}{3}\%-1\%$
In Tuberculating Waters	50–75	$\frac{1}{2}\%-\frac{1}{8}\%$	$\frac{5}{8}\%-\frac{1}{4}\%$	$\frac{7}{8}\%-\frac{3}{8}\%$	0.89–0.41	$2\%-1\frac{1}{3}\%$
Cast-Iron Pipe, small diameter	30–50	$1\frac{1}{2}\%-\frac{1}{2}\%$	$1\frac{3}{4}\%-\frac{5}{8}\%$	$2\frac{1}{8}\%-\frac{7}{8}\%$	2.02–0.89	$3\frac{1}{3}\%-2\%$
Steel Pipe	25–40	$2\frac{1}{8}\%-\frac{3}{4}\%$	$2\frac{3}{8}\%-1\%$	$2\frac{3}{4}\%-1\frac{3}{8}\%$	2.57–1.33	$4\%-2\frac{1}{2}\%$
Wood Stave Pipe	20–30	$3\%-1\frac{1}{2}\%$	$3\frac{3}{8}\%-1\frac{3}{4}\%$	$3\frac{3}{4}\%-2\frac{1}{8}\%$	3.54–2.02	$5\%-3\frac{1}{3}\%$
Wrought-Iron Service Pipes	15–30	$4\frac{5}{8}\%-1\frac{1}{2}\%$	$5\%-1\frac{3}{4}\%$	$5\frac{3}{8}\%-2\frac{1}{8}\%$	5.09–2.02	$6\frac{2}{3}\%-3\frac{1}{3}\%$
Hydrants	35–50	$1\frac{1}{8}\%-\frac{1}{2}\%$	$1\frac{3}{8}\%-\frac{5}{8}\%$	$1\frac{5}{8}\%-\frac{7}{8}\%$	1.58–0.89	$3\%-2\%$
Valves	40–50	$\frac{3}{4}\%-\frac{1}{2}\%$	$1\%-\frac{5}{8}\%$	$1\frac{3}{8}\%-\frac{7}{8}\%$	1.33–0.89	$2\frac{1}{2}\%-2\%$
Meters	15–25	$4\frac{5}{8}\%-2\frac{1}{8}\%$	$5\%-2\frac{3}{8}$	$5\frac{3}{8}\%-2\frac{3}{4}\%$	5.09–2.57	$6\frac{2}{3}\%-4\%$

* By " Cost of Structure " is meant first cost of the physical structure, including allowance for " interest during construction " and " engineering and contingencies " items, but excluding " going value " and " franchise value."

† Less than $\frac{1}{8}$ of 1 per cent.

TABLE 2.

Sinking-Fund Data.*

Life of Structure.	Annual Contributions to Sinking Fund in Percentage of First Cost, with Different Assumed Interest Rates upon Sinking Fund Accumulations.					
Years.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Variable.† (4 Per Cent. to 2½ Per Cent.)	Straight-Line Method.
5	18.8355	18.4627	18.0975	17.7396	18.46	20.00
10	8.7231	8.3291	7.9505	7.5868	8.33	10.00
15	5.3767	4.9941	4.6342	4.2963	5.09	6.67
20	3.7216	3.3582	3.0243	2.7185	3.54	5.00
25	2.7428	2.4012	2.0952	1.8227	2.57	4.00
30	2.1019	1.7830	1.5051	1.2649	2.02	3.33
35	1.6539	1.3577	1.1072	0.8974	1.58	2.86
40	1.3262	1.0523	0.8278	0.6462	1.33	2.50
45	1.0785	0.8262	0.6262	0.4700	1.08	2.23
50	0.8865	0.6450	0.4777	0.3444	0.89	2.00
55	0.7349	0.5231	0.3667	0.2537	0.73	1.82
60	0.6133	0.4202	0.2828	0.1876	0.67	1.67
65	0.5146	0.3390	0.2189	0.1391	0.57	1.54
70	0.4337	0.2745	0.1699	0.1033	0.48	1.43
75	0.3668	0.2229	0.1322	0.0769	0.41	1.33
80	0.3112	0.1814	0.1030	0.0573	0.40	1.25
85	0.2647	0.1479	0.0803	0.0427	0.35	1.18
90	0.2256	0.1208	0.0627	0.0318	0.30	1.11
95	0.1926	0.0987	0.0490	0.0238	0.26	1.05
100	0.1647	0.0808	0.0383	0.0177	0.23	1.00

* Note. — Deposits at *end* of year, compounded *annually*.

† 4 Per Cent. Sinking Fund rate for 0 to 14 years life inclusive.
3¾ ,, ,, ,, ,, ,, ,, 15 to 19 ,, ,, ,,
3½ ,, ,, ,, ,, ,, ,, 20 to 25 ,, ,, ,,
3¼ ,, ,, ,, ,, ,, ,, 26 to 35 ,, ,, ,,
3 ,, ,, ,, ,, ,, ,, 36 to 55 ,, ,, ,,
2¾ ,, ,, ,, ,, ,, ,, 56 to 75 ,, ,, ,,
2½ ,, ,, ,, ,, ,, ,, 76 up.

TABLE 3.

Annual Contributions to Sinking Fund.	Approximate Age in Years at Maturity or End of Life of Structure, with Different Assumed Interest Rates upon Sinking-Fund Accumulations.					
In Per Cent.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Variable.* ($2\frac{1}{2}$ Per Cent. to 4 Per Cent.)	Straight-Line Method.
$\frac{1}{4}$	87 years	72 years	62 years	55 years	97 years	400 years
$\frac{3}{8}$	74 ,,	63 ,,	55 ,,	49 ,,	83 ,,	267 ,,
$\frac{1}{2}$	66 ,,	56 ,,	49 ,,	44 ,,	69 ,,	200 ,,
$\frac{5}{8}$	59 ,,	51 ,,	45 ,,	41 ,,	62 ,,	160 ,,
$\frac{3}{4}$	54 ,,	47 ,,	42 ,,	38 ,,	54 ,,	133 ,,
$\frac{7}{8}$	50 ,,	44 ,,	39 ,,	35 ,,	50 ,,	114 ,,
1	47 ,,	41 ,,	37 ,,	33 ,,	47 ,,	100 ,,
$1\frac{1}{4}$	41 ,,	37 ,,	33 ,,	30 ,,	41 ,,	80 ,,
$1\frac{1}{2}$	37 ,,	33 ,,	30 ,,	28 ,,	37 ,,	67 ,,
$1\frac{3}{4}$	34 ,,	30 ,,	28 ,,	26 ,,	34 ,,	57 ,,
2	31 ,,	28 ,,	26 ,,	24 ,,	30 ,,	50 ,,
$2\frac{1}{2}$	27 ,,	24 ,,	23 ,,	21 ,,	25 ,,	40 ,,
3	23 ,,	22 ,,	20 ,,	19 ,,	22 ,,	33 ,,
$3\frac{1}{2}$	21 ,,	19 ,,	18 ,,	17 ,,	20 ,,	28 ,,
4	19 ,,	17 ,,	17 ,,	16 ,,	18 ,,	25 ,,
5	16 ,,	15 ,,	14 ,,	14 ,,	15 ,,	20 ,,
6	14 ,,	13 ,,	12 ,,	12 ,,	13 ,,	17 ,,
7	12 ,,	12 ,,	11 ,,	11 ,,	12 ,,	14 ,,
8	11 ,,	10 ,,	10 ,,	10 ,,	11 ,,	12 ,,
9	10 ,,	9 ,,	9 ,,	9 ,,	10 ,,	11 ,,
10	9 ,,	9 ,,	8 ,,	8 ,,	9 ,,	10 ,,
15	6 ,,	6 ,,	6 ,,	6 ,,	6 ,,	7 ,,
20	5 ,,	5 ,,	5 ,,	5 ,,	5 ,,	5 ,,

* See note at foot of Table 2.

TABLE 4.

Plant.	Monthly Depreciation. Rate allowed by Contractors. Per Cent.	Corresponding Life in Years by Straight-Line Method.	Corresponding Life in Years by Sinking Fund Method. 5 Per Cent. Compounded Semi-annually.
Locomotives, cars, tracks, excavators, machinery, etc. . .	1.1	7.6	6.5
Scrapers, wagons, etc., horses, mules, etc., ...	2	4.2	$3\frac{5}{6}$
Camp equipment	2	4.2	$3\frac{5}{6}$
Small tools	5	$1\frac{2}{3}$	$1\frac{5}{8}$
Boats, scows, etc.	4	2.1	2
Office furniture	1.1	7.6	6.5
Real estate	$\frac{1}{2}$	$16\frac{2}{3}$	$12\frac{1}{4}$

In this connection it may also be of interest to allude to the fact that Metcalf & Eddy, in reporting to the Boston Finance Commission in 1908 upon the cost of machinery and fair rental therefor, fixed, as an extreme monthly rental, 5 per cent. of the cost of the machinery, assuming that in the case of the larger machinery, which would be likely to have longer life, the rate should be correspondingly reduced.

The average length of life of water-works plants depends upon many factors. Broadly speaking, from 40 to 60 years probably represents the usual range of life of the structures, except in the case of very rapidly growing towns or cities.

The Wisconsin Public Service Commission, in a recent opinion upon the value of the Fond du Lac, Wis., water works,* gives the average life of the different water-works plants examined by it to date as $65\frac{1}{4}$ years.

The United States Commerce and Labor Bureau, in its Special Report upon "Statistics of Cities having a Population of over 30 000," in which are included some valuable water-works statistics, assumes a fifty-year period of life, corresponding to a 2 per cent. annual rate of depreciation upon the straight-line method of computation, but applies this to the present value of the plant. (If the going value and franchise value are *included* in the "present value of plant," this is more nearly equivalent to a 3 per cent. annual allowance for depreciation, based upon the repro-

* See page 275, *Engineering Record*, Vol. LXII, September 3, 1910.

duction cost upon which depreciation is usually figured, and would correspond in the above cited tables to an approximate period of life of 33 years, which is too short a life for average conditions.) Technically, the depreciation should be based upon the cost of the plant, though it may be applied as a per cent. of present value or gross annual income, for convenience, if errors of assumption be adjusted at intervals of 5 years more or less

The total allowance to be made for depreciation, including contingent depreciation, will probably vary between limits of 1 per cent. and 2 per cent. per annum of the reproduction cost of the property, though in many cases it may lie even beyond these limits. Data are scarcely sufficient at the present time to fix the proper allowance for contingent depreciation with a reasonable degree of accuracy. It seems reasonable to anticipate, however, that an allowance of not less than one fourth of 1 per cent. per annum upon the sinking fund basis should be provided, and in many cases — perhaps in the majority of cases — this allowance will prove inadequate. In this connection it may be of interest to cite the experience of the Knoxville Water Company, the plant of which in a period of 17 years showed an average annual rate of depreciation, exclusive of proper allowance for repairs and renewals, of 2.12 per cent.

Owing to the variation in the amount of the gross income of water works, as compared with their cost or value, the depreciation thereon, expressed in percentage of the gross income, is correspondingly variable. Broadly speaking, however, it may be said that the depreciation is likely to amount to 10 per cent., more or less, of the gross annual income of the works.

Thus, if we assume a plant having a value of \$5 000 000, a gross annual income of 10 per cent. thereof, or \$500 000 per year, and a depreciation of 1 per cent. thereof, or \$50 000 per year, the depreciation will amount to 10 per cent. of the gross annual income. Assuming value \$500 000, gross annual income 12 per cent. equals \$60 000, depreciation $1\frac{1}{4}$ per cent. equals \$6 250, the depreciation would amount to *10.4 per cent.* of the gross annual income. Assuming value \$50 000, gross annual income 16 per cent. equals \$8 000, depreciation $1\frac{1}{2}$ per cent. equals \$750, the depreciation would amount to 9.4 per cent. of the gross annual income.

How many of you gentlemen, as water-works superintendents, are charging off 10 per cent. of your gross annual income to depreciation account, unless you are doing it through the agency of a sinking fund to retire the outstanding bonds upon your works?

RATES OF INTEREST TO BE ALLOWED UPON SINKING FUND DEPRECIATION ACCOUNTS.

In the straight-line method of computing annual depreciation allowances, no question of interest rate is involved, as the fund is not supposed to enjoy any accretions. Not so in the sinking-fund method, which is founded upon the assumption that the fund *shall* draw annual interest accretions. The interest rate to be allowed in figuring the annual accretions to the sinking fund of the depreciation account is, therefore, of prime importance, having substantial effect upon the annual contributions to the fund (in principal sum and accrued interest earned upon it).

In the eastern part of the United States two general theories have found application, first, that the depreciation sinking-fund allowance should be based upon a low rate of interest allowance, such as 4 per cent., commensurate with reasonable safety; second, that it should be based upon a 5 per cent. or higher rate, commensurate with the rate of interest paid upon the company's bonds or debt, upon the theory that the depreciation fund should be invested in the company's plant, or be applied to the retirement of its bonds or the amortization of its debt.

In the Middle West a theory was developed by Messrs. George H. Benzenberg and Benezette Williams, in the Sheboygan, Wis., water-works valuation suit, in the year 1900, and has since found application in the Omaha, Neb., Peoria, Ill., Des Moines, Ia., Flint, Mich., Mobile, Ala., and other cases, based upon a variable rate of interest (from $2\frac{1}{2}$ per cent. to 4 per cent.), dependent upon the assumed length of life of the structure,—the lower rate corresponding to the longer life. This theory has much to commend it, not only on account of its conservative effect, but because it gives practical recognition to the fact that the future is inherent with uncertainty and that the banker will be unwilling to allow as high a rate of interest upon a sinking fund of long life as upon one of short life for which future conditions can be more accurately forecasted.

RELATION BETWEEN INTEREST RATE AND HAZARD.

In the final analysis, however, it makes no difference which method is adopted, *provided* the plant be permitted to earn, through the agency of its rates, a profit upon its total value or property truly commensurate with the risks of the business, *including* in the latter a consideration of the provision for depreciation. If the depreciation allowances are too small, the risk of losses resulting therefrom is correspondingly increased and the plant must be allowed to earn a higher return or profit; if the depreciation allowances are evidently liberal, conservatively figured, the equitable return to be allowed upon the property is clearly smaller. The relative division of return from equitable rates between depreciation allowance and profit is at issue between the bondholder and the stockholder, rather than the consumer and the company, and the settlement of the question is reflected in the relative value of the bonds and the stock rather than in the rates.

RELATIVE DESIRABILITY OF THE SINKING FUND AND STRAIGHT-LINE METHOD OF FIGURING AND MAKING PROVISION FOR DEPRECIATION.

The sinking-fund method is believed to comport more closely with the life history of a water-works plant than the straight-line method. From the operator's point of view, it has the merit of smaller depreciation account requirements during the early years of the formative period when the new plant is acquiring its business, due to the compounding effect of the interest accumulations in the later years of the plant's life. From the consumer's or public point of view it has the advantage of tending to equalize rates during the life of the plant, decreasing the burden to be met by the rates in the early years of few consumers and increasing with the growth in demand for water.

From the accountant's point of view the straight-line method is much to be preferred on account of its greater simplicity in application and freedom from the necessity of accounting not only for the annual contributions to the principal of the sinking fund, but also for the accretions thereto to cover interest allowances. The corrections, from time to time, for errors in assumption as to depreciation allowances are also simplified.

On the other hand, the two methods are interchangeable or convertible, and the equivalent annual straight-line contribution for a period of 5 years, for instance, corresponding to the sinking-fund method requirements for a like period, may readily be figured and thereafter more easily be applied. As previously stated, it is desirable to check up the depreciation account allowances with the property valuation and to examine the fairness of the rates at intervals of not over 10, and preferably 5, years.

THE RELATIVE DESIRABILITY OF DISTRIBUTING THE DEPRECIATION ALLOWANCES AND CHARGING THEM OFF FROM THE SEVERAL ACCOUNTS INVOLVED OR OF CARRYING THEM IN ONE MAJOR ACCOUNT.

Whether it is preferable to distribute the depreciation allowances or carry them in one account will depend upon the bookkeeping methods employed and the conditions under which the works are operated.

One general account shows, at a glance, the adequacy of the provision made for depreciation. It may be a menace and object of unjust attack, however, at the hands of the political demagogue or inexperienced critic. With the public service commission in control, or a fair-minded public, no such result should follow.

The annual distribution of the depreciation allowance has, on the other hand, the advantage of making the several accounts show correctly upon their face the book value of each structure or group of structures and is preferable upon this account, though it makes the checking of the depreciation account more laborious.

DESIRABILITY OF SEGREGATING CONTINGENT DEPRECIATION FUND FROM PHYSICAL AND FUNCTIONAL DEPRECIATION FUND.

It is exceedingly desirable to account for the contingent depreciation fund separately from the physical and functional depreciation, not only that the necessary amount may be the more accurately determined, but that when this fund has reached what may appear, or later be determined to be, a reasonable amount, no further contributions should be made to it until substantial draft be made against it, reducing the remaining balance below a safe figure

or provision. The fund will, moreover, then be subject to annual review by the governing board of the works.

SINKING FUND AS A SUBSTITUTE FOR DEPRECIATION.

As a matter of fact, while few municipalities have recognized this depreciation, or perhaps even considered the underlying theory of it, they have, in effect, made allowance for it in the sinking-fund provisions of the bonded debt; and it may be added that the sinking-fund requirements have usually been in excess of the necessary allowance for depreciation, as a result of the assumption of a shorter life for the bonds than the actual life of the structures covered by them, though, perhaps, there is a tendency to-day to issue longer-term bonds, the terms of which in some cases exceed the probable life of the structure. This practice is to be condemned unless the sinking-fund requirements correct this evil; even then this practice appears illogical.

RENEWALS.

Engineers are somewhat divided in opinion as to the necessity of charging off to depreciation any portion of renewals involving a betterment of the service. Some contend that renewals involving betterments of service — there being no difference of opinion, of course, in regard to renewals which are mere replacements of existing structures — should be charged in part only to construction; or, in other words, that the value in the original structure not previously written off in depreciation should be deducted from the construction account simultaneously with the addition to it of the increment of value in the renewal represented by the betterment of the service; while other engineers contend that the entire cost of the element of the renewal representing the betterment of the service should be charged to construction account, without any deduction on account of the remaining value in the original structure which has been sacrificed or lost, upon the theory that the betterment is demanded by increased business or larger requirements, and that hence the new business should carry the entire burden of the larger debt thus created. To take a concrete example, let us suppose that the growing needs of a community necessitate the relaying of a 6-in. pipe with a 12-in. pipe. Upon

the first theory, the water-works company would be entitled to charge to construction account only the difference between the entire cost of the 12-in. pipe and the remaining value (i. e., not yet written off) in the 6-in. pipe, the rest being charged to renewals in offset to depreciation; upon the second theory, the entire cost of the 12-in. pipe might be charged to construction account upon the theory that the 6-in. pipe was still adequate to meet the requirements for which it was laid, and that the larger main was required by the greater demands of added business, which should, therefore, carry its entire cost. Furthermore, say exponents of the second theory, the saving in interest upon the smaller original structure during its life, as compared with the larger structure had it been built, has more than covered the cost of the smaller structure; to which it is replied that this fact has no significance beyond pointing the limits of rational design.

Certainly the first theory is the more conservative, and safer from the point of view of the bondholder or owner of the property.

PLEA FOR BETTER RECORDS.

In conclusion, the writer reiterates his plea to you superintendents of water works for more complete records of depreciation or life history of the different structures making up your own water-works plants. There is urgent need of them. Partial records, — that is, records of failure, — while of substantial value, are difficult of interpretation and often misleading in character. What we need is reliable records of the full history of your plants, the records of long life and useful service as well as of early failure or abandonment for special cause.

A committee of the American Water Works Association, of which the writer chances to be chairman at present, while Mr. John W. Alvord, of Chicago, the original chairman, is serving his term as president of that association, has already been at work upon this subject for nearly two years and has accumulated a considerable amount of data. It would welcome any further contributions which you may be willing to make to its investigation of this very important and interesting subject.

DISCUSSION.

Mr. Arthur A. Reimer.* I should like to ask Mr. Metcalf whether any of the data on this subject accumulated by his committee indicate that the method of handling depreciation by a direct charge to the maintenance account has resulted in any heavy drains on the financial resources of the municipality or private company, so heavy as to cause inconvenience or demoralization. I ask this question because it is our practice not to consider depreciation as a separate account, but to handle all such charges through our maintenanee account direct, and we have never been embarrassed in any way, nor inconvenienced, though we have had some heavy renewals and heavy replacements along with what might be called our normal maintenance expenses. We have never felt that it was at all out of the way for us to care for this depreciation item through our maintenance account.

Mr. Metcalf. I don't know that I can answer that question satisfactorily. I believe it is a fact that very few water works, whether publicly owned or privately owned, have made a practice of charging off depreciation as such. All works substantially have taken care of repairs and renewals through a maintenance account, or through an operating account, to a greater or less extent. Now if your provision in this particular case has been sufficient from year to year, or in the aggregate, to meet the actual depreciation in the plant, I cannot see that you would suffer any embarrassment by charging off a certain sum annually to a depreciation account and crediting it with the work which you had actually done. That is a mere matter of bookkeeping. If, on the other hand, your appropriations for this purpose have not been adequate and you were to make them adequate, it might embarrass you. I don't know what your gross income is, or what funds you have available.

In other words, as I understand it, you say in substance that you have merely taken care of renewals from time to time out of current income as an operating charge or as a maintenance charge or renewal charge, or whatever you may have called it. You have not charged it to new construction; you have not issued new capital against it. Now, if the renewals in the aggregate have

* Engineer and Superintendent Water Department, East Orange, N. J.

equaled the depreciation in the aggregate, your works have lost nothing, and the capital has not been impaired. If, on the other hand, the renewals are not equal to the actual depreciation, there will come a time when, unless you lay aside an additional fund between now and then, you will find your capital has been impaired.

Now, it seems to me that the only way in which you can tell whether the works are in sound condition is to have some means of following up your actual allowances for depreciation, with the actual records of the plant as to depreciation, in order to determine whether you are taking care of your capital, or have been dividing your capital in dividends, if you have paid any. That, it seems to me, is the thing which you have got to be exceedingly careful of, in the light of the Knoxville decision, because the Supreme Court virtually says to you that if you haven't to date taken care of the depreciation, you cannot collect it in the future. The sum which you have failed to collect is lost. As I have said, I think that the court would recognize the condition of a new plant, which had not had the opportunity to lay aside a fund, or, indeed, of an old plant which had just been put to the expense of reconstruction. I think some leeway would be granted there. Take the case of New York, which at the present time is putting millions of dollars into new construction, a lot of which is designed to meet future conditions. It would be unreasonable, in my judgment, to require them to earn, a year after that construction, a sufficient depreciation account to take care of it. In a period of years after that, however, they must do so; only it is less burdensome to the public, as I view it, to give them a longer period of years in which to distribute that depreciation allowance than to require them to take care of it at a certain specific rate beginning immediately after the new construction. The same thing happened in Cincinnati with its new construction work, and I might cite example after example.

In other words, almost all works go through certain phases. After the works are established and are under good operating conditions, the rates may be assumed to be adequate for the service which is being rendered. Gradually the service becomes incommensurate with the rates; I mean to say, perhaps the supply

is not as large as it should be, and the service does not meet the standards of the day. Then comes a period when the works earn really too much money on the service which they are furnishing; or, to put it another way, the service is not quite adequate. Then you come to a point where the company has to make large additional capital expenditures, and the works go again through a reconstruction period, as it were, when the rates are not adequate to the additional capital expenditures which have been made. But, taking a long period of years, the average may be all right. I think the court will recognize that. I think it would not be to the public's interest to demand that the rates should be changed from year to year; they must be settled for certain periods.

Now, trying to address myself to your problem directly, I do not think that as a matter of fact most water works have laid aside a depreciation fund as such. Many of them have had sinking funds to take care of their bonds, but, as I have said, in many of those cases the bonded debt is less to-day than the value of the works. In other words, they have done more than to take care of the depreciation in the plant. Others have not done that, and have suffered accordingly.

Mr. Reimer. It was along the line of sinking-fund matters that I was thinking when I raised the point of treating depreciation through the maintenance account. Using as a basis the average life of the water bonds that have been put out by the majority of the municipalities or private companies during the past twenty-five or thirty years, if a properly figured sinking fund has been provided we find that the structures for which the bonds were issued have been paid for through the sinking fund well within the life of these structures. It is only within the past few years that we have a tendency to issue bonds of longer term than in previous years. I think you mentioned that fact and I think that you are right in the statement. This tendency will probably be more marked from now on, and is due to the fact, as I see it, that we have greater knowledge of the life of structures and perhaps a higher sense of responsibility in regard to financial matters. Certainly this is the case in the eastern part of the country. I am not familiar with western practice.

In regard to the question of charging a portion of renewals to the capital or permanent properties account, I feel that any department charging the entire cost of renewals to this account should be condemned. That portion of the cost of renewals which represents the actual increment of value is properly chargeable to the permanent properties account. I can see no good way of explaining why the entire cost of renewals or enlargements should be so charged. If we replace a 6-in. main with a 12-in. main and take out the 6-in. main, which often occurs, there certainly can be no question of adding to the permanent properties account only the increment of value due to the larger main. If, on the other hand, the 6-in. main be left in place, then I agree that the whole cost of the enlarged main is properly chargeable to the permanent properties account. This subject has been argued in my hearing by various men, and some of the arguments offered in favor of putting the entire value of the larger main into the permanent properties account where a smaller main is actually removed, using that as an illustration, are entirely fallacious, to my mind. The subject is one that is worthy of more thought and consideration on our part, and the work being done by Mr. Metcalf and his committee should be of large benefit to us in reaching a conclusion on these matters.

Mr. Metcalf. Answering your last statement, I think there is much to be said for your point of view. Of course the chief argument which the advocates of the theory which you are condemning bring forward is this: that the 6-in. pipe was put in, in the case you cite, when under the conditions an 8-in. pipe might have been put in; that they put in a smaller pipe with the idea of replacing it later, and that they have saved, therefore, in interest charges enough to make good that difference in cost. The argument does not appeal to me very strongly, but that is their ground for that view, I think. It lends color to it, at all events.

Mr. Theodore H. McKenzie.* Mr. President, there is one matter in connection with depreciation which it seems to me that Mr. Metcalf did not cover. Many of the water works in the eastern states are gravity works; I noticed that he did not mention the matter of depreciation of dams and reservoirs. For instance,

* Engineer Connecticut State Board of Health

in the works with which I am connected the reservoirs cost fully 40 per cent. of the entire cost of the works. The water is impounded by earthen dams which are fully as good to-day as when they were built, twenty-seven years ago. The life of such reservoirs is almost indefinite; it ought to be considered as not less than one hundred years.

Another matter is the water rights; that is, the right to divert water from mill owners and from other users of water. For instance, water rights for the works with which I am connected were settled in 1883 for $5 000. In 1896 I had occasion for an adjoining city to settle similar water rights, and we were obliged to pay about $33 000 for about two thirds the area of shed settled for in 1883. The probabilities are that to-day the same water rights are worth much more than they were in 1896. Nearly all the water rights in that vicinity are taken up by some city, so that they must be considered of considerable value. The items of reservoirs and water diversion have increased in value more than the pipe system has depreciated.

Another matter which occurred to me: When many of the water works in the eastern states were built, from 1870 to 1890, pipe was worth $40 a ton, — in some places $42 to $45 a ton. To-day the cost of pipe is from $20 to $23 a ton, and there is not much probability of the price going higher. I do not know how Mr. Metcalf would consider the matter of depreciation with reference to pipe, which then cost $42 a ton and now is worth $22, whether he would provide a sinking fund to pay the cost of renewal of the pipe or to cover the original cost of the pipe, or what he would consider the depreciation or appreciation in the value of the water rights of dams and reservoirs.

Mr. James L. Tighe.* I would like to ask if any of the members here are aware of any municipality which has established a depreciation fund for taking care of these things.

The President. I think, Mr. Tighe, that there are a great many cities which have a sinking fund to provide for the payment of the bonds.

Mr. Tighe. I mean a sinking fund in connection with the depreciation.

* Engineer Water Works, Holyoke, Mass.

The President. It amounts to the same thing.

Mr. Tighe. I do not think so, Mr. President, as a sinking fund formed for the payment of debts of no specified amounts, and anticipated only, must be different from a sinking fund formed for the payment of a specified debt already incurred, such as a bonded debt.

In the state of Massachusetts the legislature does not favor giving permission to borrow money now except on the serial bond basis, so that the old and very useful long-term sinking fund has practically been abolished in Massachusetts.

Mr. Edward S. Cole.* It seems to me there is such a thing as depreciation by leakage. For example, in Chicago the Bureau of Water Surveys, which it was my pleasure to start some years ago, has recently reported, as the result of district measurements covering a considerable area of the city, that only one third of the total pumpage in Chicago is used by consumers, one third is wasted at leaky fixtures, and one third is lost underground. Such a distribution system has depreciated very greatly by reason of its excessive leakage and waste, thus increasing the cost of operation not only in pumping expense, but in interest account for extensions made necessary to maintain adequate service in spite of leakage.

When such a system is to be purchased by a municipality it would seem that its value as a revenue-producing property is somewhat impaired. It costs too much to buy and too much to operate.

In my own opinion, this depreciation by leakage is represented by far more than the cost of making the system reasonably tight, and the exact method by which it receives its proper allowance in the valuation of water-works plants should be carefully considered.

Mr. William F. Sullivan.† Mr. McKenzie spoke of the appreciation of water rights, of land values, and of the increment from other sources. This increased value of water rights with no monetary appreciation often becomes a burden on a water company with a fixed income, and as often a city or town exacts additional taxes for the increased valuation. My point is, that such

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* Consulting Engineer, New York.

† Superintendent, Pennichuck Water Works, Nashua, N. H.

appreciation is not tangible, and money cannot be readily realized or obtained from such increase, and that you cannot from such increment lay water pipes, build dams, or install pumps, for the increased value is only on paper so far as a water works in concerned. Looking at appreciation from this point of view, it often is more of a liability than an asset, and does not always offset depreciation.

Mr. Emil Kuichling.* Every private corporation that is about to be appraised for municipal ownership finds out that depreciation is a real and practical thing, and in most cases it becomes the cause of serious dispute. The representatives of the city usually call for a depreciation of much higher percentage than an expert would think of allowing. If one company is to be bought out by another, it also figures very seriously.

The great trouble is that we have so few reliable data. When called upon to exhibit the actual observations upon which we fix our rates of depreciation, the showing is generally unsatisfactory. Most of our data are of comparatively ancient origin, and are not based upon the apparatus and materials used at the present time. On searching the literature of the subject, it will be found that many of the figures are based on mere opinions, expressed many years ago before some commission or tribunal, and have been carried along by a variety of authors without any alterations founded on later experiences. This fact serves to emphasize Mr. Metcalf's strong appeal for a new set of figures. When these become available the subject will be on a much better basis than it is now.

A movement of this kind was started about twelve years ago in the American Water Works Association, and resulted in the publication of some valuable statistics about American pumping engines and boilers by Mr. John W. Alvord in 1903. It is to be hoped that this good work will soon be extended by the presentation of similar data, relating not only to pumping engines and boilers, but also to standpipes, reservoirs, conduits, distributing pipes, valves, hydrants, buildings, and all other details of a water-works plant.

Mr. McKenzie. I want to add one word with reference to

* Consulting Engineer, New York.

the methods considered by Mr. Metcalf, if applied to the valuation of a water works. A water works which has a good water supply has presumably been extended on the lines where the population has increased so that there is a large number of people, probably ten times the population that were on the lines of the system when it was first built; and that matter should be taken into consideration in estimating the value of the works. That is, if it is a good going concern, and has a good water supply fed by gravity, it should be considered with reference to its earning capacity as well as with reference to the depreciation of the plant. The earning capacity of the works is a larger factor in determining the value of a water works than the actual cost price of reproducing the plant.

Mr. Metcalf. Mr. President, in answer to some of the questions which have been put to me, — I think I did refer to the depreciation allowance upon reservoirs, and put the life from fifty to one hundred years; and dams would, perhaps, come under the same general category. What Mr. McKenzie says about reservoirs I have no doubt is true. There is, however, this consideration which should not be overlooked, — that in the case of reservoirs functional depreciation may become an important element. That is, the growth of the community may require getting new sources of supply, which will make the old smaller sources of comparatively little value to the works. Under those circumstances I think he would agree that the reservoirs which he has to-day would have a less value to the works. If there is any fall in value through depreciation, then the cost, the capital, I submit, is entitled to be protected, and it should be taken care of through the agency of the rates, whatever method of accounting may be used, whether you take care of it through a sinking fund or a depreciation account.

Mr. Tighe has, I think, put the case clearly, and the President in answering him, that the majority of communities do not write off depreciation as such, but they have sinking funds for their bond issues, which more than take care of the depreciation. If you will examine the government statistics, which have been printed in the report to which I referred, in the years 1905, 1906, and 1907, which are now available, you will see that in a majority

of cases the value of the works as reported by them is probably considerably less than a true valuation of the plant. That simply means that the additional cost has been taken care of in the past through a sinking fund.

As to the question of water rights which Mr. McKenzie has raised, I think he has answered his own question. They appreciate generally rather than depreciate, consequently their writing off would be by way of lessening the depreciation allowance which must be made upon the entire plant. In a consideration of value, of course the water rights must be considered. I have not attempted to go into the question of valuation of works or the bearing of the depreciation question upon that value, because it is a very large subject, and it seemed to me that depreciation in itself was a large enough problem to present to you at this time. In general, and answering Mr. McKenzie's question, it seems to me that in the light of sound public policy the rates should take care of whatever loss in value there may be in any given period of years through depreciation. If the works have not earned it in the past, as I interpret the recent opinion of the Supreme Court of the United States in the Knoxville Water Company case, they cannot hope to earn it through the agency of rates in the future. Provision must be made for it substantially from year to year. But the opinion of the Supreme Court certainly does warrant their collecting an adequate fund in the future to take care of the depreciation.

Answering Mr. Cole's question, it seems to me that the subject relates rather to the operating expenses of the works than to any question of depreciation. As he has rightly said, the additional pumpage of water resulting from the leakage has served to swell the operating cost, and probably the maintenance cost, of the works. Now, it is to be assumed that the rates which have been earned in the past were predicated upon the existing conditions of operation, including these allowances. If in the future our standards of water-works practice should be raised, and money can be saved on that score, certainly it should be recognized in the rates. And in saying that I do not think that the company is entitled to the full enjoyment of saving in that direction. As to the effect of the fall in cast-iron pipe from $40 or $50 or $60 to

$25, again I would say that the capital invested in the plant at the time that cast-iron pipe was selling for $40 or $50 or $60 is entitled to protection, and if we see falling markets, if we know that the price of cast-iron pipe in any period of years is likely to decrease, we are justified in so proportioning the rates as to take care of that loss in value. It is only by doing that that you can get capital to go into projects of this sort, and it is for the public good that it should be done.

THE PRESIDENT. It seems to me that this is an oportune time to mention a conference which was held in Washington last May on uniform accounting for water works. At this conference, called by Dr. Powers, statistician of the census, there were present representatives from the American Water Works Association, the New England Water Works Association, the Certified Public Accountants Association, the Public Service Commission of Ohio, the Interstate Commerce Commission, and some other public commissions. There was drawn up a system to recommend for accounting by water works, and of course this question of depreciation was much discussed. This report, I think, will later be published by the census, in what form I cannot tell you, but I think it is to be published in serial form by the journal of which Mr. Muller, of the Interstate Commerce Commission, is editor. It is called *The Government Accountant*, and is published at 425–429 Bond Building, Washington, D. C. I think that those of you who are interested in this subject will find much there of interest.

MEMORANDA RELATIVE TO THE CITY OF ROCHESTER.

BY EDWIN A. FISHER, CITY ENGINEER, ROCHESTER, N. Y.

[*Read September 24, 1910.*]

The city of Rochester is situated in the county of Monroe, state of New York. The center of the city is about 7 miles south of Lake Ontario. The central portion of the city is about 260 feet above mean lake level and 510 feet above mean tide water.

The Genesee River flows through the city from south to north and has an aggregate fall of about 257 feet within the city limits. There are three principal falls within the city: the Upper Falls, of about 100 feet, near the New York Central & Hudson River Railroad; the Middle Falls, of about 25 feet, and the Lower Falls, near the northern portion of the city, of about 100 feet.

The Genesee River has a watershed of about 2 500 square miles. The flow ranges from a minimum, during the dry months, of from 150 to 200 second feet to a maximum flood of from 35 000 to 45 000 second feet. The water power of the river is utilized. very largely, by the Rochester Railway and Light Company.

The Erie Canal, passing through the city from west to east, was originally an important factor in its development. At the present time, however, the presence of the canal within the city limits has interfered with the development of certain portions of the city. The state is now constructing what is known as the "Barge Canal," which will take the place of the Erie Canal. Its location is about three miles south of the center of the city, passing through the Genesee Valley Park.

SEWERAGE.

We have within the city limits about 260 miles of sewers, all of them at present emptying into the Genesee River. Plans have been prepared, and are now before the state commissioner of health, providing for an intercepting sewer to take the sewage

out of the river to a purification station located near the shore of Lake Ontario and about two miles east of the Genesee River, where, after passing through the purification plant, the effluent will be discharged into Lake Ontario at a distance of about 7 000 feet from shore, into water 50 feet deep.

PAVEMENTS.

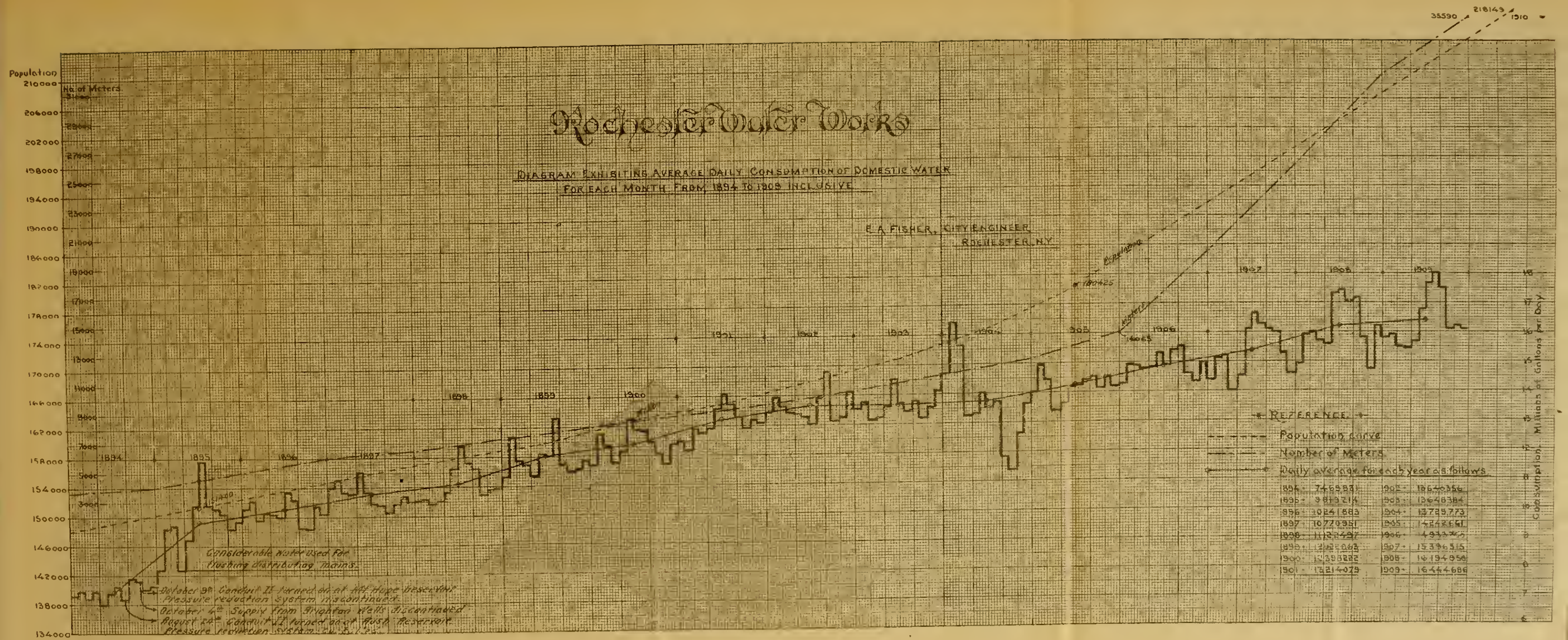
We have about 350 miles of streets, of which about 190 miles are improved as follows:

About 65 miles of asphalt,
15 miles of Medina block stone,
19 miles of common Medina stone,
45 miles of brick,
43 miles of macadam or gravel, and
3 miles of miscellaneous.

The pavements, sewers, and other similar improvements are constructed under what is known as "local improvement ordinances." These ordinances provide, generally, that the entire cost of the work shall be assessed, in the case of a pavement, upon the abutting property, and, in the case of a sewer, upon the drainage territory. This method of paying for such work is exactly the opposite of the practice in many New England cities where the entire cost of such work is defrayed from the general fund.

While our method, in many cases, imposes a hardship on the abutting property, it has resulted in increasing very largely the amount of improved streets over what there would have been had the opposite practice been followed. As a matter of fact, out of probably 150 ordinances for such work, adopted each year for several years past, we have had scarcely any objection from the property owners.

Another feature of our pavement work, in connection with water mains, is that in our main streets occupied by street railway tracks we lay two sets of pipes, one on each side of the street, so that the services do not pass under the railway tracks. In our investigations for electrolysis we have found no material damage by electrolysis to any of our water mains, but did find quite a number of cases of service pipes that had been damaged from that cause.


Rochester Water Works
DIAGRAM EXHIBITING AVERAGE DAILY CONSUMPTION OF DOMESTIC WATER
FOR EACH MONTH FROM 1894 TO 1909 INCLUSIVE
E. A. FISHER, CITY ENGINEER,
ROCHESTER, N.Y.
Population
No. of Meters
Consumption. Millions of Gallons per Day.
REFERENCE.
Population Curve
Number of Meters
Daily average for each year as follows.
1894 - 7465931
1895 - 9819214
1896 - 10241683
1897 - 10720951
1900 - 12398222
1901 - 13214079
1902 - 13640366
1903 - 13648384
1904 - 13725773
1905 - 14242661
1907 - 15396515
1908 - 16194956
1909 - 16444686
Considerable water used for flushing distributing mains.
October 9th Conduit II turned on at Mt Hope Reservoir. Pressure reduction system discontinued.
October 4th Supply from Brighton Wells discontinued.
August 24th Conduit II turned on at Rush Reservoir.
35590
218149
1910

STREET LIGHTING.

The city is lighted under contract with the Rochester Railway and Light Company. We had, on July 1, last, 3 761 arc lights and 312 tungsten lamps, making a total of 4 073 electric lights.

The spacing of the arc lights in the residence streets is generally 400 feet, unless, on account of intersecting streets, or for other reasons, this distance has to be modified. In the central portion of the city the spacing is very much closer, and in Main Street the average distance is about 80 feet. The appropriation for street lighting for the year 1910 was $239 000.

The arc lights connected with the overhead system cost $58.00 each, and, when connected with the underground system, $68.00 each, per year.

ELECTRIC SUBWAYS.

The Railway and Light Company has 71 miles of underground conduit, and the Bell Telephone Company has 60 miles. This amount of underground work is increased from year to year, and we expect in the near future that the main portion of the city will be entirely free from wooden poles and overhead wires.

This city has the reputation of being one of the best, if not the best, lighted city in the United States. It also has a reputation for the most extended use of electric power of any city.

It may be stated here, that the management of the Railway and Light Company, which owns and controls practically all of the electric and gas service in the city, is such as to commend itself to all our citizens, and also to serve as an object lesson to other municipalities in the manner of handling public service corporations.

PUBLIC MARKET.

This city is surrounded on the north and east by rich agricultural land devoted quite extensively to market gardening. During the season from 1 000 to 1 500 teams come into the city to sell and deliver garden truck.

Up to the year 1905 these gardeners used our own main public streets on the east side of the city during the night and early

morning. At that time the city purchased about ten acres of land and established a wholesale public market, affording accommodations for 1 200 teams within the market limits. The market has been successful from the start, and has proved a great convenience both to the market gardeners as well as to the city.

CONVENTION HALL.

Another branch of municipal work which has recently been taken up is providing a convention hall and an exposition hall for conventions and other public gatherings. The Convention Hall will seat about 3 800 people; and connected with it is the Exposition Hall, having about 3 600 feet of floor space.

The city has also recently acquired from the state a tract of land of about 42 acres, a portion of which will probably be devoted to the purposes of industrial expositions. This city has, through the activities of the Chamber of Commerce and the city officials, come to be recognized as one of the leading convention cities of the country.

WATER WORKS.

The present water-works system was constructed in the years 1873–74. Prior to that time extensive investigations had been made by several engineers as to the source of supply, and among those investigated were Lake Ontàrio, the Genesee River, and Hemlock Lake. It was decided to construct gravity works for a domestic supply, taking water from Hemlock Lake, — about 30 miles south of the city and about 390 feet above its general elevation, — and at the same time to construct an auxiliary fire service, taking water from the Genesee River.

So far as I know, this city was the first to establish a separate system of water works for fire protection, and this system at present covers more territory than any other in the country. The total length of pipe is about 20 miles. The capacity is at the rate of 13 million gallons per day. While it does not compare in working pressure to the few modern systems recently installed in some of the larger cities, yet it is, and has been from its inception, a very material addition to the efficiency of the fire department. The pressure during fires is maintained at 140 pounds.

The domestic system of water works covers the entire city, and consists of about 350 miles of pipe. There are about 4 000 hydrants connected with this system.

The area of the watershed of Hemlock Lake, and Canadice Lake and outlet tributary thereto, is about 66 square miles. The capacity is about 29 to 30 million gallons per day. The water is brought to the city in two gravity conduits, one completed in 1874, composed of 9.62 miles of 36-inch wrought-iron pipe, 3 miles of 24-inch wrought-iron pipe, and 15.5 miles of 24-inch cast-iron pipe. The wrought-iron pipe is made from $\frac{3}{16}$ inch- to $\frac{1}{4}$-inch plate. The capacity of this conduit is about 6.5 million gallons per day. A second conduit, completed in 1894, is composed of a 6-foot brick horseshoe-shaped tunnel 2.25 miles in length, and a 38-inch riveted steel pipe 26.19 miles in length. The steel pipe is made up of plates from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in thickness. The ultimate capacity of this pipe is about 16.5 million gallons.

It may be of interest here to refer to an official test made of the Holly, or Fire, System, on February 18, 1874.

A 2-inch stream was thrown vertically 210 feet, many feet above the top of the figure of the goddess of justice on the old Court House. A 3-inch vertical stream was thrown from a point near the corner of State and West Main streets 285 feet. A 4-inch vertical stream was thrown to an elevation of 294 feet. The same stream was thrown horizontally a distance of 365 feet. A 5-inch vertical stream was thrown to an elevation of 256 feet. These are some of the tests made, with reference to which the late Mr. J. Nelson Tubbs, then chief engineer of the water works, said, "It is believed that this was the most remarkable exhibition of large streams ever made in any country, and as such it attracted widespread attention from the hydraulic engineers, compelling the introduction of larger factors in the hydraulic formulas used to determine the results to be obtained from large streams with liberal size pumping mains."

Referring to the quality of the water of Hemlock Lake, the following quotation from an address before your Society* in June, 1887, by Prof. A. R. Leeds, Ph.D., of the Stevens Institute of Technology, may be of interest.

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* Journal New England Water Works Association, Vol. II, page 79.

"It seems to me astonishing that at the present time, so far as I know, only two large cities in the country have water of unexceptionable quality. These I believe to be Brooklyn and Rochester. None of the others, taking them in their descending order, Washington, Baltimore, Philadelphia, New York, and so on down, none of the larger cities in this country, with the exception of the two I have mentioned, as far as I know, have water of unexceptionable quality."

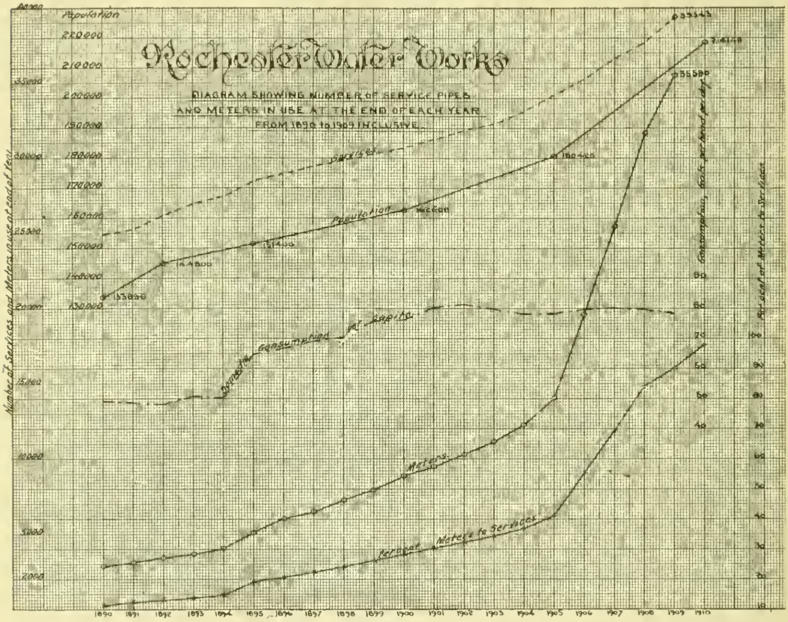

FIG. 1.

DIAGRAM SHOWING INCREASE IN POPULATION, NUMBER OF METERS AND SERVICES; AND CONSUMPTION.

Referring to Fig 1, showing increase in population, number of meters, and amount of water used, it is interesting to note that Mr. Tubbs, in referring to this matter in the year 1889, in a speech before the Common Council, said, with reference to a suggestion that a reduction in the amount of water used could be made by the wholesale introduction of meters: "It would require more than 19 000 of these to cover the services at present unmetered, and

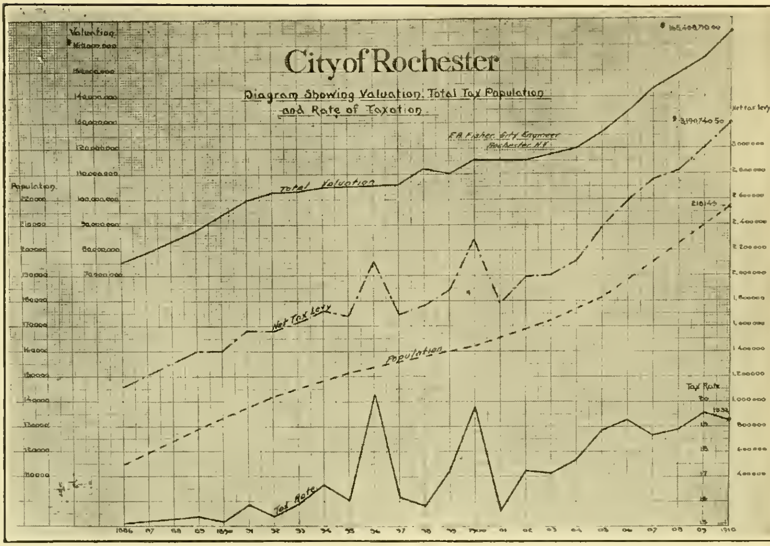

FIG. 1.
DIAGRAM SHOWING INCREASE IN POPULATION, TAX RATE, AND NET TAX LEVY.

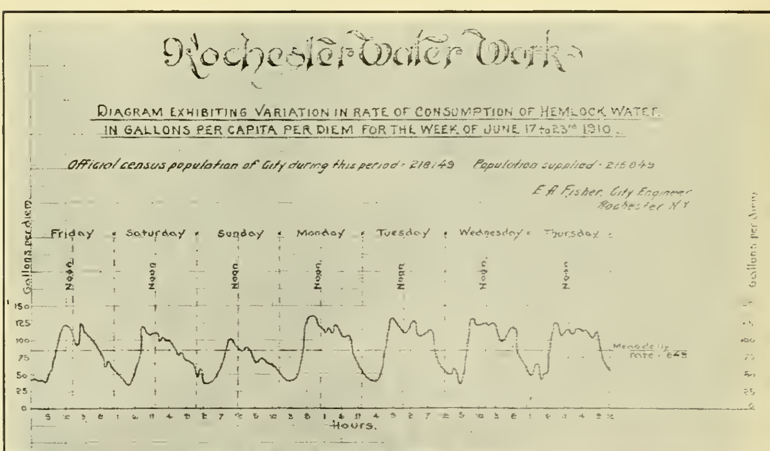

FIG. 2.
DIAGRAM SHOWING VARIATION IN RATE OF CONSUMPTION.

take at least three years' time; and when this was done the natural accretion of population would have taken all the water saved by the process." The diagram shows that this statement was actually borne out by facts from the year 1904 to date, when practically the entire city has been metered. The increase in population, and in use of water due to a larger population, has taken up all the water saved by the introduction of meters.

CITY GOVERNMENT.

At a meeting of what is known as the "City Lunch Club," Saturday noon, last, a gentleman from Buffalo talked on "Commission Government for the City of Buffalo." He said, among other things, that interest in a change of municipal government was general throughout the country.

This is neither the time nor the place to discuss any new method of municipal government, and anything that I may say is not intended to advocate any particular method, but to describe the system in operation in this city.

In the year 1900 this city came into what is known as "Second Class Cities," and a so-called uniform charter was adopted by the legislature for the cities of Rochester, Syracuse, Albany, and Troy.

By virtue of a constitutional amendment, adopted in 1907, this city came into what is known as "Cities of the First Class," and on January 1, 1908, a new charter applying only to this city went into effect. The special feature of this charter, as well as the charter for cities of the second class, is that it sharply divides the city government into branches, the legislative and the executive.

The legislative branch is composed of the Common Council, the members of which are elected from each of the 22 wards. The president of the Common Council is elected by the city at large. The Council has very large legislative powers, and it is not necessary for the city to ask for special legislation at Albany for any of the ordinary operations of the city government. The Council has power to issue bonds and notes for any improvement which it may authorize, limited only by the constitutional provision that the indebtedness shall not exceed ten per cent. of the assessed valuation. This body has no executive functions. The

mayor has veto power over the ordinances of the Common Council, but the charter contains the usual provision that ordinances may be passed over his veto by a two-thirds vote.

The executive branch of the city government is, in theory and in fact, controlled by the mayor. The mayor has the appointment, and without confirmation, of the corporation counsel and the city engineer, who, together with the president of the Common Council, the comptroller and the mayor as president, constitute what is known as the "Board of Estimate and Apportionment." This board fixes the number of employees in all departments and bureaus of the city, and also fixes the salaries of all officers and employees, except in a very few cases where the salary is fixed by the charter.

This board also prepares and submits to the Common Council an annual estimate of the expenses of the city for the current year. It also has other extensive powers, some of them in approval of acts of the Common Council.

A second board, called the "Board of Contract and Supply," is composed of the mayor, the commissioner of public works, appointed by the mayor, the corporation counsel, city engineer, and the comptroller, an elective officer. This board has the letting of all contracts for city work, excepting for schools and parks, whenever the work or material costs more than $250.00.

This board also approves of requisitions for work for all departments, except, as stated, for amounts less than $250.00.

The executive business of the city is subdivided into the following departments. The Department of Public Works: The commissioner of public works is the head of this department and appoints, to serve during his pleasure, a superintendent of public works, superintendent of streets, a sealer of weights and measures, and the numerous other officers and employees necessary to carry on the department. The Board of Estimate and Apportionment determines the number of employees and their salaries.

The Department of Public Safety: The commissioner of public safety is the head of this department, which includes the Police Bureau, the Fire Bureau, the Health Bureau, and the Bureau of Buildings. The commissioner appoints the heads of these bureaus, and has general control of their operations.

The corporation counsel, appointed by the mayor, has the

PLATE III.
N. E. W. W. ASSOCIATION,
DECEMBER, 1910.
FISHER ON
THE CITY OF ROCHESTER, N. Y.

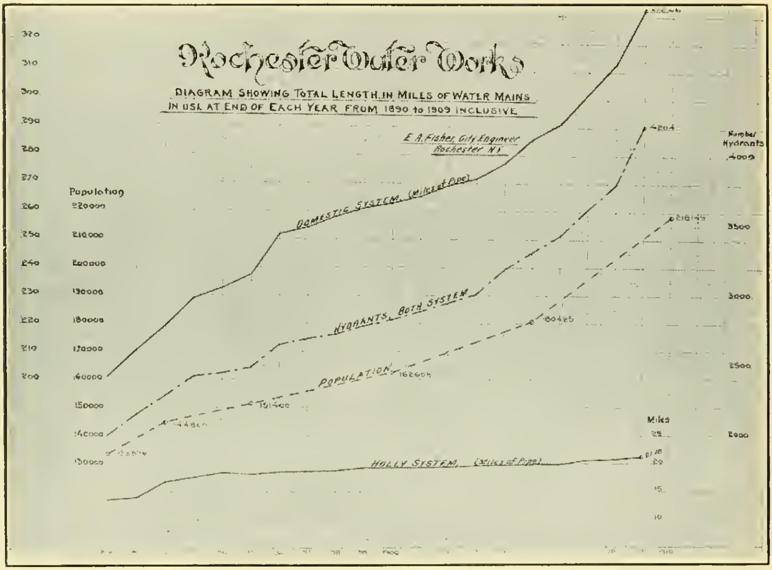

FIG. 1.

DIAGRAM SHOWING MILES OF PIPE AND NUMBER OF HYDRANTS.

appointment of all of his subordinates, and has charge of all the legal business of the city, and, as before stated, is a member of the Board of Estimate and Apportionment and the Board of Contract and Supply.

The city engineer, also appointed by the mayor, has charge of all the engineering for the city, with the exception of parks and schools. He also is a member of the boards of Estimate and Apportionment and Contract and Supply, also of the Public Market Commission and of the Examining Board of Plumbers. He has charge of the maintenance of all city buildings, except school buildings and such as are used exclusively for the Department of Public Safety.

The heads of the various departments are appointed by the mayor at his pleasure, and without confirmation. The mayor, therefore, has absolute control over the executive departments of the city.

The mayor also appoints the park commissioners, who serve for a definite term. This Board of Park Commissioners has the supervision of the public parks. He also has the appointment of the Board of Examining Plumbers and of the market commissioners, and of quite a number of other minor officers.

Among the other elective officers is a board of four assessors which has charge of the general assessment of the city and also of special assessments for local improvements, or for other purposes.

The school board, consisting of five members, is also an elective board, and almost entirely exempt from control by any other branch of the city government, provided it does not ask for an appropriation exceeding $25.00 per capita of the registered pupils. For an appropriation exceeding that amount it is subject to the approval of the Board of Estimate and Apportionment and the Common Council.

There are also two municipal court judges elected, and one police court judge.

ROCHESTER PARKS.

BY C. C. LANEY, SUPERINTENDENT OF PARKS, ROCHESTER, N. Y.

[*Read September 21, 1910.*]

Rochester has five large parks: The Genesee Valley Park, situated on the upper river, contains about 500 acres, of which about 18 acres are devoted to golf, and about 10 or 12 acres to a polo and athletic ground; there are also a swimming pool, three baseball diamonds, seven tennis courts, two children's playgrounds, and a very beautiful grove in which there is a fine band stand, where during the summer there is music by the Rochester Park Band at least one day in the week. One prominent amusement is boating and canoeing on the upper Genesee, about twelve miles of the river being used for this purpose.

Highland Park, about 50 acres in area, was virtually given by the celebrated nurserymen, Elwanger & Barry. They first gave 20 acres and stipulated it should be devoted to an arboretum, and that some celebrated landscape gardener should be employed to make the design. The landscape gardener employed was Frederick Law Olmsted, the father of the Olmsted Brothers who are now employed by the city. He saw that the park was too small for an arboretum, and so he recommended a shrub collection and a pinetum. The shrub collection has been established, and every shrub that can be made to grow in this part of the country is growing in Highland Park. The pinetum is a collection of all the coniferous evergreens that will grow in this part of the country, taken from all parts of the world. A part of the shrub collection is a collection of lilacs, of which there are about 210 varieties, including all the different species and all the varieties that have been discovered so far. We also have a fine collection of hardy rhododendrons and the hybrid rhododendrons that are a cross between the American and those growing in Asia. We have also a collection of peonies, of about 210 varieties, not to mention quite a number that have not yet been named. All the shrubs are labeled with the common and with the scientific name. Besides

the peonies, we also have a collection of 27 varieties of magnolias, all the kinds that have been discovered so far that will grow in this climate. The southern magnolia, the magnolia that many southern people think is the only magnolia, is not hardy enough to grow as far north as Rochester. It grows as far north as Washington. Sometimes when our southern friends come up here and see the magnolias on Oxford Street they say, "Why, these are not magnolias," but when they see our collection they realize that there are other magnolias than the beautiful southern magnolia which they so greatly admire.

In Seneca Park, on the high banks of the Genesee River, we have about 140 acres of land. This park is planted mostly to the choicest of American trees. With very few exceptions there are no foreign trees in this park. There is a lake of 5 acres on which there are swan boats for carrying small children. In the winter this lake is kept clear of snow to allow skating. There is a small collection of animals, most of which are indigenous to this country. Many of the native birds and some foreign birds are in the aviary.

Maplewood Park was formerly a part of Seneca Park, and is on the left bank of the river. It was found inconvenient to manage the two parks on opposite sides of the river as one park, so they took the part of Seneca Park on the left bank of the river and called that Maplewood Park, naming it for the beautiful maple grove which is at the corner of Driving Park Avenue and Lake Avenue. At that corner we have established a rose garden in which are planted many of the choicest hardy roses.

At the lake we have Durand-Eastman Park, of about 500 acres. The land was given by Dr. Durand and George Eastman, of Eastman Kodak fame. The roads have been partly graded through the park. Recently a number of deer and a few other animals have been put into this park as an attraction. I think at the present time the people of Rochester do not fully appreciate this park, but at the rate that the city is growing now, in a very few years it will be found indispensable. A special feature of the park will be the facilities for bathing in Lake Ontario.

Besides the playgrounds in Genesee Valley Park, there is a children's playground at Maplewood Park, one at Seneca Park, one at Brown's Square, one of the most thickly populated parts of

the city; one at Thomas Street, and another at Hartford Street, both of which are in congested districts in which the children are mostly of poor parents. All the playgrounds are in charge of experienced instructors.

A children's pavilion was erected in Highland Park by Elwanger & Barry, at a cost of over seven thousand dollars, and dedicated to the children of Rochester in 1890. From this pavilion Lake Ontario, seven miles away, and the Bristol Hills, thirty-five miles away, may be seen on a clear day.

A RAMBLING DESCRIPTION OF THE ROCHESTER WATER WORKS.

BY BEEKMAN C. LITTLE, SUPERINTENDENT.

[*Read September 22, 1910.*]

Many times, while urging the members of this Association to visit us at Rochester, I have been met with the statement that we had nothing novel, intricate, or interesting in our water-works plant to show. My first feelings were of chagrin that such a complaint should be made, but these were quickly followed by feelings of pride, until second thought had to place such remarks under the heading " Important, if true."

Think of it! A water-works plant in its thirty-eighth year, so finely modeled years ago and so well managed since, that in its running nothing new is required and a humdrum existence is permitted its superintendent, whose gray matter is not disturbed by the solving of any problems! Two hundred and twenty thousand people served with water by some 38,000 service pipes and a like number of meters; 350 miles of sundry pipe, cast iron, wrought iron, steel, galvanized iron, black iron, lead and lead-lined, in sizes varying from $\frac{1}{2}$ inch to 36 inches; two entirely separate and distinct systems of water pipe, one a high-pressure pumping system (the oldest in the country — used exclusively for fire protection, and the other a gravity system, used for domestic purposes as well as protection against fire. All of these, and yet nothing to interest a water-works engineer! It is too wonderful and good to be true.

In the thirty-eight years we *have* had to make changes and renewals of equipment, for old things *do* wear out, but credit should be given to some of those things that have stood the wear of time. We still have in use, regularly, the old Holly quadruplex steam pumping engine and the two water sets that were put in originally in 1872–3 for our high-pressure fire service, and I believe the chief engineer of the pumping station has an affection for these deeper even than he feels for the splendid new centrifugal pumps lately installed, one electrically driven and one operated by steam turbine, each of 3 million gallons capacity.

We have still doing service a number of our original hydrants. We are, to be sure, gradually taking them out, but not any more because they are worn out than because they are now too small to serve for the proper protection of the buildings and business houses which have grown up around them since they were installed, nearly forty years ago.

For the same reasons, large numbers of our valves and mains are being replaced, and yet many of these old mains and valves are found to be in good condition to-day. In particular, the cast-iron mains in our domestic system seem to be remarkably well preserved. In some cases there is almost no tubercular growth, and very little sediment is found. This fact, of course, is due probably more to our excellent water than to any virtue in the cast-iron pipes. In a number of localities on our high-pressure or Holly system, in place of removing mains and relaying larger ones, we have had the old mains cleaned, by contract. The work was satisfactory and the results very gratifying. This high-pressure system of pipes uses the Genesee River water, which is non-potable and exceedingly roily at times. In these pipes we find large deposits of silt and much tubercular growth after years of service. The cleaning machines remove them both equally well, with no bad after-effects that we have discovered.

While pleased with the results of our contract for pipe cleaning, I question the wisdom of the cleaning companies when they bid, as is their custom, — or at least was with us in our contract, — so much a foot for cleaning, regardless of whether the pipe is five feet underground or a foot and a half, as it may be in New Orleans; whether it is under a granite block pavement or in a dirt road; whether there may be service taps of various sizes every 20 feet to look after, or none at all, as in our high-pressure system; whether the machine may have a clear haul of 1 000 feet, or a cut in the main and pavement has to be made every 200 or 300 feet. I should certainly say that the prices for pipe-cleaning contracts should be determined by considering local conditions in each case.

In addition to the old mains and valves and hydrants which we are still using with good satisfaction, we have water passing through a number of old meters that were installed about thirty

years ago. The conclusion may be reached in time that there is practically no limit to the life of a meter, any more than there is to the life of a good watch, if it is taken care of and parts repaired or renewed as occasion requires. There is no reliable answer to the question, "How long will a meter last before it wears out?" As to how long it will register accurately without attention, that is another matter. We find that with our exceptional water, which is free from grit and has a uniform pressure, the disk meters are apt to register closer after long use than the piston or current types. This may not obtain in other places, where conditions are different.

To the writer, the behavior of our disk meters is remarkable. In 1905 we had fifteen $\frac{5}{8}$-inch disk meters removed for test, from residences which they had served for seven years. There were five meters, each from the three different manufacturers from whom we had been purchasing. The meters had all been set in service the same month of the same year and, seven years later, were removed and tested within a month of each other. The locations were selected at random and there was nothing unusual about the care which they had received from the householders. These fifteen meters were brought to the shop and tested without being cleaned or repaired in any way. On full-flow test, every single one registered within 2 per cent. of perfect. On the leakage test, with a $\frac{1}{32}$-inch stream, eleven of them registered within 5 per cent. of perfect, or better; one of the remainder registered 9 per cent. in favor of the consumer, one 22 per cent., and two would not register until the stream was increased somewhat. The registration of the meters for the seven years varied from 18 000 cubic feet — or 2 500 cubic feet a year — to 86 000 cubic feet, or 12 300 cubic feet a year. This highest registration meant a water bill of about $13.00. Although all of these meters were set back in service, some without being taken apart and cleaned even, the only repairing made in order to have each one register perfectly before the resetting was to one disk, which had to be refitted.

This test was made in order to find out which of the three makes was giving the best satisfaction, and, to our great satisfaction, it was found that all three were best. Three one-inch disk meters

were also tested, which had been in service four years each. Two of these registered within 2 per cent. of perfect on both full stream and leakage test, and the other registered 3.7 per cent. on full flow and 17 per cent. on the leakage test in favor of the consumer. These meters had each registered an average of about 75 000 cubic feet a year.

These tests satisfied the writer that in Rochester, at least, it would not pay to remove all meters frequently for test, in order to save money, on the theory that the meters would under-register after several years' usage. That is, if the total amount of the water bills represented by the registration of these meters were increased by the per cent. which the meters were found to under-register, the difference would not be sufficient to pay for the trouble and time spent in testing the meters. These tests that have been enumerated were, as stated, made five years ago, after seven years' use. These meters were again removed last July, after twelve years' service. All but two registered within 2 per cent. of perfect on full flow, these two being 5 per cent. and 6 per cent. out of the way, respectively. On a very small leakage test, three would not register and the rest averaged $5\frac{1}{2}$ per cent. out of the way. Of course, after these tests were made, each meter was cleaned, all necessary repairs made, and each was set back only after it registered perfectly on both full stream and leakage.

The older meters which we have in use are of the rotary piston type. Recently eight of the oldest ones, of $\frac{5}{8}$-inch size, were removed. These were set in 1880 and 1881, twenty-nine and thirty years ago. Before cleaning or repairing, they averaged for accuracy less than 4 per cent. out of the way, on full flow, and about 11 per cent. on leakage test. These, of course, have been repaired or removed perhaps a number of times in the thirty years of use, but my point is that they are still in use and giving good service.

The use of meters in Rochester, now 98 per cent. metered, has undoubtedly kept our consumption down below what it would otherwise have been. While this does not mean saving in dollars for coal and extra pumping engines, ours being a gravity supply, it does mean that we have put off for a number of years the great expense of another conduit line and saved the interest on such a large investment. Long before this, without meters, we would

have exhausted the capacity of our present conduits. Of the larger cities of this country, there are few, if any, that have a smaller daily per capita or per service consumption than Rochester.

Practically all of our small services are of 3-A lead from the main to the curb. The plumbers lay them, under our supervision, after we have put in the corporation cock, and then the services are maintained at our expense. We suffer very little from electrolysis. The conditions here have been exceedingly good in this respect since the street railway company bonded all of its joints by electrical welding, and the company now makes frequent tests of its trackage system to see if the return is in good condition.

Our street mains are cast iron and our policy on the domestic system is not to lay any smaller that eight inches. Some 6-inch mains are laid, but only on cross streets, where the system is well gridironed. We install valves in abundance, and thus avoid the necessity of shutting off large sections in cases of leaks or breaks. Nearly all hydrant branches have valves; they are 6-inch, with some few 8-inch branches for the extra large hydrants. The small mains (especially 4-inch), laid years ago, are being replaced rapidly by the larger sizes.

On our high-pressure or Holly System we are, in our new work, installing nothing smaller than 12-inch mains. We allow private fire services, for standpipes, automatic sprinklers, and yard hydrants, to be taken from either our Holly system or the domestic system, but not from both. That is, the sprinkler equipment in a building cannot be connected up with a service from each system, even with a check valve between. The river water which we pump directly into our Holly system is so polluted that it would be a great menace to health to trust a check valve to keep the two supplies separate. Insurance underwriters do not like this rule, but have to put up with it.

On several of these private fire services, where there are yard hydrants, we have installed detector meters, and we intend to have them all metered eventually. On an ordinary service, the consumer pays for the meter, but on private fire services we have adopted the plan of furnishing the meter free, unless, or until, it is found that the water is used for other purposes than for extinguishing fires. In such cases we insist on the property owner

paying for the cost of the meter and the installation, as well as for all water used

We have two gravity conduits leading from our source of domestic supply, 30 miles away. The older one, laid thirty-six years ago, has caused, all told, but little trouble, either in the 14 miles of wrought-iron main or the 16 miles of cast-iron pipe of which it is composed. The second conduit consists of 38-inch steel riveted pipe, varying in thickness from $\frac{1}{4}$ to $\frac{3}{8}$ inch. This was laid sixteen years ago, and we have had considerable trouble with pitting on this conduit. For the past eight years we have, each summer, uncovered varying lengths and carefully scraped the old coating off and repainted the pipe with two coats of mineral rubber and two coats of graphite paint. On the sections thus recoated, we have had no further leaks and the pitting has not advanced appreciably. The probability is that the entire length of this steel pipe will eventually have to be thus treated. The pits or holes which occur, causing the leaks, are small and do not necessitate shutting off the conduit in order to make repairs. A wooden plug is pressed into the hole, a patch of lead placed over it, and over that is placed a square steel patch $\frac{3}{8}$ inch thick. Then this is all held in place, close against the pipe, by two half circles of wrought iron placed around the pipe and drawn tightly together by bolts.

From our source of supply, Hemlock Lake, which is seven miles long and half a mile wide, these two conduits lead first into a small storage reservoir about ten miles south of the city, and then from there down to the two distributing reservoirs on the southern boundary of Rochester. The purity of the supply is very well insured, as the city owns practically the entire shore of the lake, leaving but a few cottages on its entire 15 miles of shore-line. These cottages and residences are watched and inspected by water-works employees, and the garbage, etc, removed and buried off the watershed as often as necessary. The entire watershed of the lake is kept track of. The population of the 48 square miles is very small, and all cases of disease are reported, and any that may have possibilities of danger to our water supply are investigated and taken care of, if necessary. There is a small town of 600 inhabitants three miles south of Hemlock Lake, and,

while it is situated on the watershed, with the drainage all toward the lake, we have never had any bad results shown in our water supply. Conditions in this village are particularly watched by an inspector who resides there nearly all of the year and reports to the superintendent every week.

Only once in the last fourteen years since we started taking regular weekly bacteriological and chemical observations has the bacillus colon appeared in our water supply, and never has there been a case of typhoid fever in Rochester which has been traced to our water supply. Throughout the entire year of 1909 there were only 17 deaths from typhoid fever, or only one to every 12 000 people, and the average yearly rate for the past ten years has been only one death to about every 7 500 inhabitants. No other of the larger cities of New York state has a record like this. In fact, the only place at all which equals it is Yonkers, with a population only one third as large. It has been pretty well determined that all of the typhoid that we have had is contracted outside of the city. For instance, last year 70 per cent. of the typhoid cases were reported in September and the following months, after vacationists and excursionists returned from summer trips to places where Hemlock water was not available.

We have been troubled with algæ, and as far back as 1876 fishy flavor and odor were complained of. While the trouble has been with us more or less through all these years, it was not until the present year when it was long continued that active measures were taken to abate the nuisance. We dosed our largest reservoir with copper sulphate, after locating the trouble there and cutting off the reservoir from the rest of the distribution. This was done last May, and our trouble vanished quickly and we have had no complaint since. The treatment was found to be so simple in application and so efficacious in results that hereafter it will be tried on much less provocation than caused its trial this year.

Except for this one trial treatment of copper sulphate, our domestic water has never been doctored in any way, nor does it undergo any filtration whatever. We believe that it well deserves the place it occupies in the very front rank of the domestic waters of the country, if not of the world.

PERTINENT MATTERS RELATING TO THE ROCHESTER WATER WORKS.

BY FREDERICK T. ELWOOD, COMMISSIONER OF PUBLIC WORKS, ROCHESTER, N. Y.

[*Read September 24, 1910.*]

In connection with pertinent matters relating to water works, I thought it might be interesting, before the able papers on the various details, to give you a very brief talk on the evolution of the Rochester Water Works.

Early in the experience of every hamlet and village arises the need of a water supply for the protection of property against destruction by fire. At a later time, when the population becomes greater and the habitations more dense, with the consequent contamination of the soil, comes the necessity for a supply of water for domestic purposes other than the primitive wells.

From the earliest times the bucket brigade has been the first method adopted by a village to fight a fire, to develop with the growth of the village, through the different stages of fire apparatus, to a modern equipment. Rochester was not an exception to the rule, and her first bucket brigades dipped water from the Genesee River or pumped it from nearby wells until 1824, when the completion of the Erie Canal furnished a new source of supply. Later, reservoirs were built under the streets to supply the hand engines, but it was not until 1874 that the first stream was turned on from a hydrant. It must not be thought, however, that the question of water works had been sleeping during these fifty years. As the city grew, the natural supply became insufficient for protection, the wells were contaminated, and the water unfit for use for domestic purposes; there was much discussion and much demand for an adequate service.

In 1835 the legislature granted a charter to the first Rochester Water-Works Company, a private corporation, with a capital of $10 000. History does not reveal that this company accomplished

more than to effect its organization. In 1852 another company was chartered under the same name, authorized to expend the proceeds of $800 000 in bonds and $800 000 in stock. This company proposed to take water from Honeoye Creek, the outlet of Honeoye, Canadice, and Hemlock lakes, at Smithtown, sixteen and one-quarter miles from the city, conducting it by gravity to the distributing pipes by means of a 24-inch wooden conduit. In 1871 the company had finished its conduit, had partially completed a storage reservoir of 70 million gallons capacity about ten miles from the city and a small reservoir near the city, and had laid thirteen and one-half miles of distributing pipe. It was then found by test and examination that the wooden conduit could not be relied on, that the leakage was so great at the depressions that only a small percentage of water passed over the adjoining elevations, and that the amount reaching the distributing system was almost infinitesimal. The company had expended all its funds, but was reorganized and offered to replace the wooden conduit with iron pipe in consideration of a rather heavy yearly rental; but the people had become discouraged and suspicious of private water companies, so in 1872 the legislature created a board of water commissioners and authorized the city to construct and operate its own water system. The city finally purchased for $26 000 the distributing system and some land at Hemlock Lake from the old company. The uncompleted storage reservoir on the Henrietta road still remains as its monument.

Immediately on the appointment of the board of water commissioners the planning and construction of our present system was begun. It is not within the province of this paper to go into any detail, but simply to relate in a general way what has been accomplished. The plan adopted after much discussion was to construct a double system: a pumping plant, taking water from the Genesee River and using its own separate distributing system, for fire protection, and a gravity system for domestic purposes, taking water from Hemlock Lake in Livingston County, twenty-eight miles to the south of the city and at an elevation of 388 feet above the Erie Canal Aqueduct. The lake is a little less than seven miles in length and has an average width of three fifths of a mile. It is situated in a deep narrow valley in a sparsely settled district,

almost entirely surrounded by high bluffs. Its beaches are of shale; its water mostly supplied by springs. It has a surface area of 1 828 acres and a drainage area of 43 square miles.

The pumping system, with a daily capacity of 7 million gallons, was completed in February, 1874, and the tests were eminently satisfactory; in fact, they attracted, at the time, the attention of hydraulic engineers throughout the country. The greater part of the original machinery is still in use and, with its later additions, is furnishing, besides fire protection, power for hydraulic elevators and lift bridges

The conduit from Hemlock Lake was completed in January, 1876, and on the 23d of that month Hemlock water was flowing under the streets of Rochester, two years and eight months after the first pick was struck into the ground. The conduit commences in Hemlock Lake, 1 000 feet from shore, where the mouth is in thirty feet of water, and, after passing through the gate house, passes over hills and across valleys, through fields and along roads, to Rush Reservoir, about 20 miles from the lake. The bottom of this reservoir has an elevation of 224 feet above the Erie Canal Aqueduct; it has a capacity of 70 million gallons. Outside the reservoir is a by-pass by means of which the direct pressure from the lake may be thrown into the city. From Rush the conduit follows mainly along the highway to Highland and Cobb's Hill reservoirs on the outskirts of the city. This conduit furnished an unlimited supply of water until 1885, when, so rapid had been the growth of the city, the conduit was being used to its full capacity. Steps were immediately taken to procure an additional supply, and the construction of a second conduit to Hemlock Lake was finally decided on. During the next few years the water was husbanded with great care, but despite the precautions, the city narrowly escaped a water famine in 1888; a temporary supply became necessary and this was procured from artesian wells furnishing about 500 000 gallons daily.

The second conduit with a capacity of 15 million gallons was completed in 1894. This conduit commences 1 600 feet from shore at a depth of 35 feet. The first two miles is of brick tunnel 6 feet in diameter, protected from damage by pressure by an overflow chamber. From this point it is of 38-inch steel pipe, extending

over practically the same route to the same reservoirs as the old conduit.

These two conduits are now furnishing to the city an unstinted supply of the purest water of any city in the country. The conduits are supplemented by a storage reservoir at Rush, with a capacity of 70 million gallons, a distributing reservoir at Highland Park with a capacity of 25 million gallons, and our lately completed Cobb's Hill Reservoir with a capacity of 140 million gallons.

And now a word as to why our water is so pure. Hemlock Lake, with its high, thickly wooded ridges, is one of the most beautiful lakes in the country. Its beauty naturally attracted the summer cottager, and, in the early days of its use as a water supply, its shores were liberally sprinkled with cottages. During this time a strict patrol of the lake was maintained, the beaches kept cleaned and all foul matter collected in pails and buried outside the watershed. Gradually the city has acquired by purchase a strip 200 feet wide along almost the entire shore line, the cottages have been removed and the shores are slowly returning to their primitive state. The patrol is still maintained, but its work is comparatively light.

Canadice Lake, which lies less than two miles from Hemlock Lake and parallel to it, will soon be used as an additional source of supply. This lake is similar in its natural surroundings and quality of water to Hemlock Lake. It is a trifle over three miles in length and one third of a mile in width, and has a water surface of 648 acres. Its elevation is about 500 feet above the Erie Canal Aqueduct, or about 112 feet above Hemlock Lake. The outlet empties through a narrow gorge into Hemlock outlet about one fourth of a mile from the foot of Hemlock Lake. The fall from the foot of the latter to the junction of the two outlets is only about two feet, so that a small dam constructed below this point would divert the entire outflow of Canadice Lake into Hemlock, thus adding to the water supply of the city about 9 million gallons daily. The total capacity of the two lakes is about 28 million gallons per day. The same sanitary precautions in use at Hemlock Lake are being put into effect at Canadice, and the city has already acquired more than half the shore line. When the work is completed the entire watersheds of both lakes will be practically without

habitations with the exception of one small village and the scattered farms, and these are under constant supervision.

Our abundance of water is used as a factor in our street cleaning. The main streets and the avenues leading to the parks are flushed three and four times a week, removing the flour dust impossible to remove with the brooms during the day. Last year 9 million gallons of water was used for this purpose, flushing 8 500 000 square yards of pavement at a cost to the department of $11.55 per thousand square yards. From the flushing we derive a two-fold benefit, — the cleansing of the streets and the flushing of the sewers.

An important factor in a water-works system, and one which appeals very strongly to the writer, is the method of accounting. Soon after assuming office an investigation of the system in use in the accounting department showed it to be very unsatisfactory in many ways, the chief of which was that it did not in any manner harmonize with the assessors' rolls and showed an entire lack of coördination.

With the object of remedying these defects, as well as to avoid the annual delay in spreading the unpaid water rents on the tax roll, a thorough investigation of the old system was made, and, after a careful study of the conditions, it was decided to install an entirely new set of registers, ruled to show meter rate, flat rate, or frontage tax, as the case might be, on each page.

The accounts have now been arranged by wards and alphabetically by streets, and in the order of house numbers on each street, making each ledger self-indexing without regard to change of ownership. Under each account a full record is kept of all charges against the property for water, either metered or flat rate, together with a record of the service.

An account is opened with each lot in the city, so that, if water pipe is laid in the street, a charge for frontage tax or for the use of water must appear. This frontage tax never before appeared on the records, and the new arrangement greatly simplifies the work of transferring unpaid accounts at the end of the year.

A cordial invitation is extended to any one interested in this particular line to inspect our system in detail.

A pertinent matter came to the writer's attention during our

big fire of 1904. We were obliged to send to Syracuse and Buffalo for assistance, but on the arrival of the outside companies it was found that their hose couplings would not fit our hydrants. Only after a very costly delay were the proper reducers secured and adjusted. The question arose, at that time, of adjacent cities adopting a uniform size for hose couplings and hydrant connections. I think this is a question which might properly come before this convention.

COBB'S HILL RESERVOIR, ROCHESTER, N. Y.

BY JOHN F. SKINNER, PRINCIPAL ASSISTANT CITY ENGINEER, ROCHESTER, N. Y.

[*Read September 22, 1910.*]

This reservoir was proposed in 1891 by Mr. Emil Kuichling, then chief engineer of water works, not only as a distributing reservoir, but for providing additional storage close to the city, against an interruption in the operation of the conduits.

When Conduit II was constructed in 1893 and 1894, a branch was left for later connecting it with Cobb's Hill Reservoir. Ten years later, in 1903 and 1904, 60 acres of land was acquired on the hill at a cost of $123 000. The property was valuable, as at that time it was the best available sand and gravel deposit near the city.

Plans for a reservoir to contain 144 million gallons were prepared and the contract was awarded, July 20, 1905, to Denniston & Co., of Rochester, for $390 805. There were ten bidders, five above and five below the engineer's estimate of $475 000. The work was let at unit prices, ten items appearing in the bidding sheet. As usual in such construction, some additional work developed, so that the final estimate amounted to $504 778.76.

The highest part of the hill was wooded and had to be cleared. A shallow valley occupied a portion of the center of the hill, and the higher ground on each side of this valley was utilized for the embankments.

The reservoir is about 1 500 ft. long by 600 or 700 ft. in width. It is an irregular ellipse and often referred to as the shape of a baby's left foot, the hollow on the north side indicating the position of a gravel pit about 120 ft. deep. This pit was refilled, but the reservoir embankment was kept on original ground in all but two places, — a small pit at the east end and a larger area at the mouth of the natural valley, above referred to, at the west end, just south of the location of the gatehouse. This valley was filled with selected material and rolled in 4-in. layers, making a very compact foundation for the reservoir wall. A tower was constructed at the west end overlooking the work, from which monthly photographs of progress were taken. The excavation was done

FIG. 1.

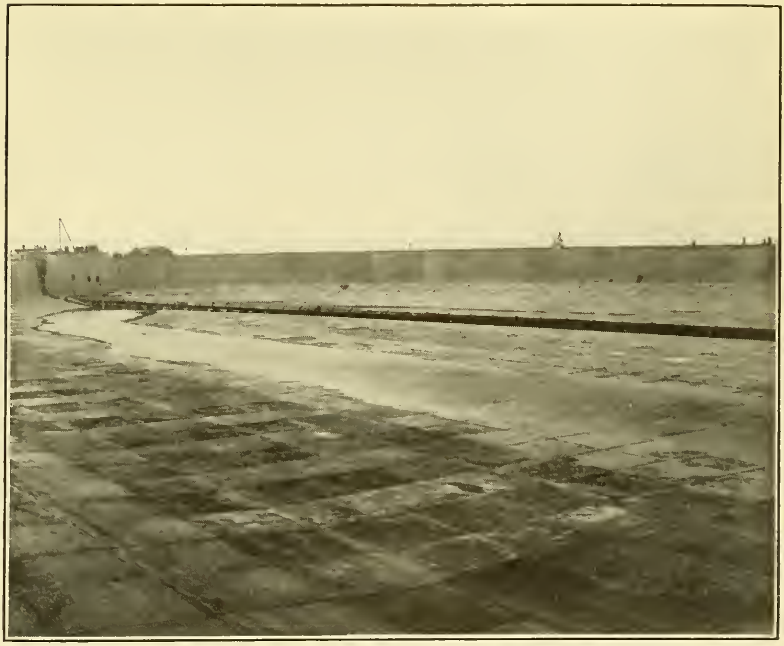

FIG. 2.

COBB'S HILL RESERVOIR. VIEW OF WALLS AND BOTTOM COMPLETE.

by steam shovel and cars and, in general, the material was ideal for this kind of work.

The reservoir was lined with concrete throughout. The bottom consisted of a 3-in. course of concrete laid continuously in long strips, for convenience about 14 ft. wide; to this the waterproofing was applied, consisting of six moppings of hot coal tar pitch and five layers of single-ply coal tar felt. Above this came the top layer of concrete 6 in. thick, laid in 12-ft. squares with pitch joints.

In anticipation of the cracking of the lower layer of concrete directly beneath the joints in the upper layer (due to change of temperature in the water), which might result in a fault and a rupture of the waterproofing layer, the lower layer of concrete was thickened to 6 in. beneath the joints in the upper layer, and steel reinforcement was placed transversely to the line of the joint in this thickened portion. An interesting laboratory experiment extending over a long period, with the temperatures changed artificially, indicated this method of treatment.

The reservoir wall, constructed in separate blocks of mass concrete, 20 ft. in length, rests upon a foundation course about 18 in. in depth, laid in blocks 10 ft. long. The transverse joint between the foundation blocks was offset 6 in. from the joint between the wall blocks, so that a reduction in the length of a wall block, due to contraction, would not crack the foundation block beneath the joint. The waterproofing of the bottom of the reservoir was carried under the toe of the wall for 2 ft., but at the joints between the wall blocks it was carried 3.5 ft. further to connect with the stop-water or key-way between the wall blocks. This key-way consisted in a channel 8 in. square, set diamond-wise 1 ft. from the face of the wall, half in one block and half in the next. This opening was filled with clay and sand, rammed with a light pile driver specially constructed for the purpose. These 20-ft. wall blocks contained 106 cu. yd. of concrete. A central passage was left through the wall, which saved about one cubic yard per linear foot. This passage is for inspection, the wall being 3.5 ft. in thickness both in front and back of the opening.

A telltale pipe 1 in. in diameter was built into the foundation blocks every 20 ft., opening at one end into the tunnel passage and, at the other end, into the sand and gravel beneath the toe of the

foundation block, the purpose being to indicate by a jet of water into the tunnel if a break occurred in the lining near the foot of the wall. Up to the present time no indication of this kind has been recorded. This tunnel is 7 ft. high and is lighted by electricity. The leakage through the joints in cold weather amounts to about 20 000 gallons per day; in warm weather, it is scarcely appreciable. Recent gagings show less than a gallon per minute for the 3 600 linear feet of wall.

It was originally intended to make a concrete of screened sand and gravel, but early in the work this was changed to run-of-bank, the latter being uniformly good. Volumetric measurements of voids in the material were made daily during the construction of concrete, and it was found that one bag of cement to 6 cu. ft. of sand and gravel produced a concrete a trifle denser than an artificial mixture of 1 part cement, $2\frac{1}{2}$ parts sand, and 5 parts clean gravel.

The wall blocks were generally built in two shifts, no stop being allowed until 2 ft. above the top of the tunnel, though some blocks were made in a single shift. They were built alternately, the intermediate blocks being constructed after the first forms had been removed. The concrete was prepared in a Hains' mixer, dumped into 1-yd. buckets on cars hauled by locomotives, and then handled by a McMyler crane. Ten forms were built for the wall blocks and used repeatedly, as 180 blocks were constructed. The material was brought to the mixer on a belt conveyor, and the concrete for the bottom was hauled on an industrial track by a home-made gasoline motor.

As the reservoir bottom and banks were so securely built, it was thought best to protect the weakest spot, viz., where the 36-in. cast-iron inlet pipe and the two 36-in. cast-iron outlet pipes pass from the gatehouse beneath the high bank at the west end of the reservoir. This was accomplished by constructing a concrete pipe gallery 126 ft. long beneath the bank, leaving openings in the heavy roof of sufficient size to admit a 12-ft. pipe in case of repairs. The 36-in. inlet pipe is laid through the gatehouse and into the reservoir, resting on saddle blocks on the reservoir bottom. It passes through the fountain chamber in the center of the reservoir, which contains a 24-in. riser for the fountain, and just beyond

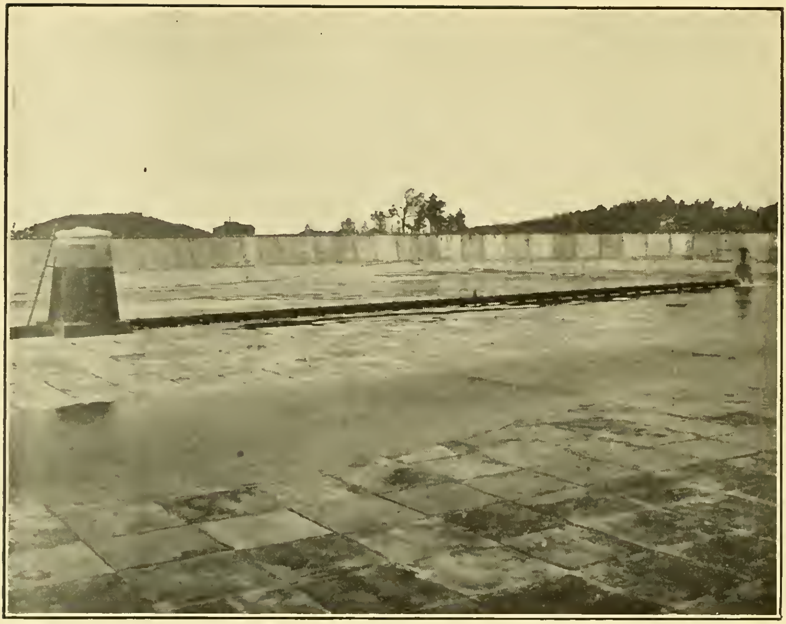

FIG. 1.
WATER BEING LET IN FOR THE FIRST TIME THROUGH SUBMERGED INLET.

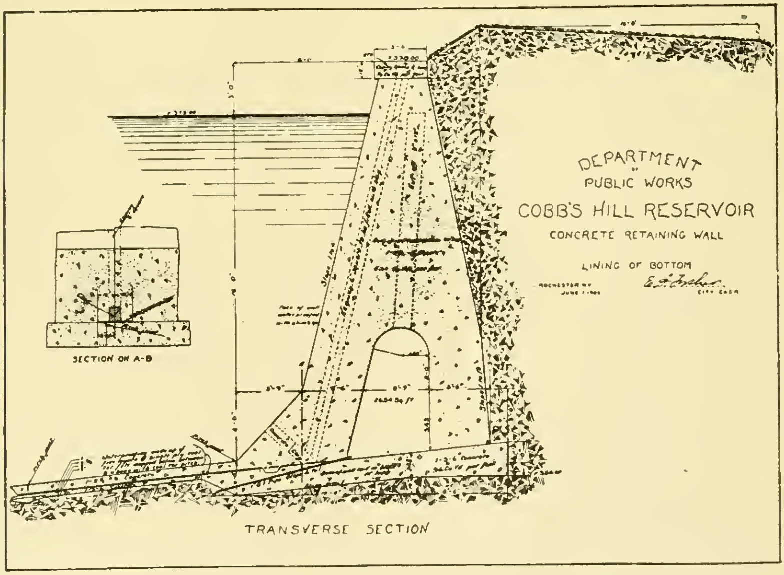

FIG. 2.
CROSS-SECTION OF RESERVOIR WALL.

the riser a 36-in. hydraulically operated gate. The pipe then continues to a submerged discharge located in the center of the circular east end of the reservoir. By closing the "fountain gate," the fountain is put into operation. By opening this gate, the water passes the fountain and enters the reservoir through the submerged discharge.

The reservoir bottom is in general level (with the exception of very slight slopes to facilitate drainage) to a line 50 ft. distant from the toe of the wall. From this line it rises on a 10 per cent. slope to the toe of the wall. This detail did not decrease the total capacity of the reservoir a great deal, but did materially reduce the quantity of masonry in the wall blocks.

The gatehouse substructure is built in the bank at the west end, projecting a little in front of the wall into the reservoir. There are six openings in the front wall, one high and one low 2- by 4-ft. gate into each screen well, a 2- by 4-ft. waste gate at the lowest point, and an arched opening to the overflow chamber, ordinarily submerged. The overflow chamber is provided with a spillway 13 ft. long over which high water may waste directly into a storm water sewer. The gate chambers are immediately back of the screen wells and below the surface level of the water. The gates, made by the Rensselaer Manufacturing Company, are operated hydraulically and can be operated manually by engaging a loose nut in the thread of the rising stem through bevel gears. The tunnel through the reservoir wall is entered from the gatehouse so that inspection can be readily made.

Water was first let into the reservoir October 19, 1908, and the reservoir was completely filled by the following January. On the 8th of April, a 60-mile gale blew from the west, throwing considerable spray over the bank. It was gratifying to note that the solid wave did not, in any case, mount the wall, the reservoir being full and the top of the coping being 3 ft. above high-water level. On the 13th of April, a 30-mile gale blowing from the south also agitated the surface considerably.

The superstructure of the gatehouse was constructed of Barre granite with a green tile roof. A portico was suggested, as the property is to be used as a park and this porch can be used as a shelter. At the foot of the hill, on Monroe Avenue, a by-pass

house was constructed. In it are duplicates of the gates in the gatehouse, as well as by-pass gates for cutting the reservoir out of operation.

A public comfort station is nearing completion on the brow of the hill near the gatehouse. It is built low and will be secluded with shrubbery.

In June, 1909, the water was lowered to make a repair on two of the wall blocks in which it was found that excessive tamping of the clay in the joint had cracked off the face. The cement was rather slow setting, and although the concrete was excellent, it had not yet attained sufficient strength to stand the ramming when the clay was put in.

As the grounds are open to the public, a steel picket fence 6 ft. high was constructed around the reservoir. The fence is built upon a 2-ft. coping, and the sloping bank inside of the fence is paved with concrete down to the reservoir wall coping. Outside of the fence, an 8-ft. concrete sidewalk has been constructed, and a row of pine trees set 16 ft. apart. The slopes have been seeded and driveways constructed, making a beautiful pleasure ground with a sightly outlook over the city. Incandescent lamps have been installed above the line of the fence as a protective measure as well as an addition to the park.

Five specially designed balanced valves for operating the hydraulic gates have been placed in a glass case in the gatehouse, and a gage has been devised for exhibiting at all times the level of water in the reservoir and in the screen wells. This is accomplished by partially exhausting the air above the water surface in the gage glasses.

The area of the water surface in the reservoir, when filled, is 18.6 acres, and the maximum depth of water is 25 ft. Its contents, as stated above, is about 144 million gallons.

Mr. Frederic P. Stearns was consulted in the preparation of the plans and specifications, and Messrs. Dow & Smith were retained in connection with the pitch waterproofing, and Olmsted Brothers in connection with the landscape work.

The reservoir has been in constant operation since its construction and has proved satisfactory both in design and workmanship.

THE PURIFICATION PLANT OF THE ROCHESTER AND LAKE ONTARIO WATER COMPANY, ROCHESTER, N. Y.

BY JAMES M. CAIRD, CHEMIST AND BACTERIOLOGIST, TROY, N. Y.

[*Read September 21, 1910.*]

The power and purification plant of the Rochester and Lake Ontario Water Company is located on the shore of Lake Ontario, about one and one-fourth miles west of the village of Charlotte, N. Y.

Lake Ontario, the inexhaustible source of supply, is 180 miles long, 60 miles wide, with an area of 6 300 square miles. The greatest depth is supposed to be about six hundred feet, while the rise and fall is about fifty-four inches. The drainage area, within New York State, is 12 400 square miles, or about one fourth the area of the entire state.

The intake, which is about one and one-fourth miles west from the lighthouse pier at the mouth of the Genesee River, is of 24-inch cast-iron pipe extending four thousand feet from the shore in water forty feet deep.

The plant was placed in operation on the fifteenth day of December, 1904, and daily records have been kept since January, 1905. In January, 1905, the total pumpage was about one million gallons per day, while at the present time the average pumpage is over four million gallons per day.

The water is sold in a part of the city of Rochester and to several suburbs thereof. All water is sold by meter, there being at the present time 2 000 meters in use. The distribution system is composed of about forty miles of mains, the sizes of which range from four to twenty inches.

The power for operating the plant is obtained from three water tube boilers of three hundred horse-power each. Previous to the autumn of 1907 the lake water flowed direct to the suction of the high-duty pumping engines which forced the water through the filters and into the distribution system. There are two high duty

cross-compound Corliss fly-wheel type pumps, each of three million gallons daily capacity.

The filter plant consists of eight pressure filters, each 8 feet diameter and 25 feet long, having a sand area of 200 square feet each, or a total of about one twenty-seventh of an acre. There is a pressure of 235 pounds on the filters. They are washed when they show a frictional resistance of 15 pounds. About two and one-half per cent. of the water filtered is used in washing the filters. When the filters are cleaned the frictional resistance is about four and one-half pounds when operating at the rate of 81 million gallons per acre per day. A resistance of 7 pounds is shown when operating at the rate of 148 million gallons per acre per day. The sand in the filters is about 3 feet in depth, has an effective size of .46 mm., uniformity coefficient of 1.51, while 60 per cent. is finer than .74 mm.

A standpipe which is 15 miles from the pumping station is used as a storage reservoir. This standpipe is 150 feet in diameter and 20 feet deep, having a capacity of 2 640 000 gallons.

Lake Ontario is subject to severe storms, and at such times the water becomes quite turbid and contains large numbers of bacteria. When the lake became turbid from a storm it was impossible to remove the turbidity by the filters, although the bacterial efficiency was satisfactory, as the coagulant did not have sufficient time to entangle the finer particles which made up the turbidity. To overcome this condition a coagulation basin was installed and placed in operation in the autumn of 1907, since which time no trouble has arisen from turbidity of the filtered water. This coagulation basin, which is of wooden construction, is 6 by 48 by 201 feet and contains about 430 000 gallons. The installation of the coagulation basin has resulted in the saving of water used for washing filters, while the total bacterial efficiency of the plant is somewhat higher. The water is lifted by a low lift pump to the coagulation basin and flows by gravity to the suction of the high duty pumps. It is not necessary to operate the coagulation basin when the turbidity of the lake water is below 10 parts per million.

Several tests of the plant were made before the basin was installed, the average bacterial efficiency being 87.38. per cent. During these tests all samples of the unfiltered water contained the coagu-

lant, as no provision had been made whereby samples of the untreated lake water could be obtained. Since the installation of the coagulation basin provision has been made so that it is now possible to obtain samples of the raw water before the coagulant has been added.

Sulphate of alumina is used as a coagulant; at times calcium hypochlorite is also used. The use of the calcium hypochlorite has greatly reduced the cost of operation, while at the same time the high bacterial efficiency is maintained. The average amount of sulphate of alumina used is about 0.7 grams per gallon, equal to about 100 pounds per million gallons of water. The average amount of calcium hypochlorite used is .048 grams per gallon, or about 6 pounds per million gallons of water. In 1907 a building was erected for the chemical tanks, storage room, and laboratory. The coagulants are dissolved in wooden tanks, 5 feet in diameter and 15 feet high, and are applied to the raw water through gravity orifice feed boxes.

Some trouble, due to the odor and taste produced by algæ in the raw water, has been encountered in the operation of the plant. At the time of the algæ troubles the following organisms were found in the raw water in large numbers.

September, 1907.	January, 1909.	February, 1910.
Dinobryon.	Cymbella.	Cocconema.
Navicula.	Fragilaria.	Cyclotella.
Synedra.	Synedra.	Synedra.
Cosmarium.	Eudorina.	Microcystis.
Crenothrix.	Crenothrix.	Crenothrix.
Volvox.	Cladothrix.	Volvox.
Nitzschia.	Stephanodiscus.	
Asterionella.	Asterionella.	
Anabæna.	Himantidium.	
Tabellaria.	Cocconeis.	
Cœlastrum.		

It is to be noted that the algæ gave trouble during the winter months on two occasions. To relieve the trouble due to the algæ, copper sulphate has been used with good success.

At the time of the algæ trouble of February, 1910, an attempt was made to treat the growth with calcium hypochlorite, but the

results were not satisfactory. Sufficient hypochlorite was used so that the treated water gave the reaction for free chlorine.

Commencing with April, 1909, daily chemical and bacterial examinations of the water from various parts of the system have been made, the work being in charge of Mr. John F. Amos, chief engineer.

The composition of Lake Ontario water during the year (April 1909 — 1910) was as follows.

Results in Parts per Million.

	Maximum.	Minimum.	Average.
Turbidity	80	0	9.5
Color	25	0	5.0
Alkalinity	99	92	96.3
Hardness	110	96	103.5
Per C.C.			
Bacteria	59 600	50	5 807

The bacterial efficiency of the plant during the year was as follows:

Bacteria removed by basin	89.28	per cent.
Bacteria removed by filters	49.60	" "
Bacteria removed, *total*	96.60	" "

Calcium hypochlorite was used during part of the year.

The average bacterial efficiency of the plant during April, May, June, and July, this year, was 99.23 per cent.

The filtered water is always free from color and turbidity, the efficiency in this respect being 100 per cent. During the year, 1 017 samples of 1 c.c. each of the raw water were examined for B. Coli-communis; 293, or 28.8 per cent., gave positive results. Of the 758 samples of 1 c.c. each of the settled water examined, 31, or 4.0 per cent., gave positive tests for B. Coli-communis. Of the 1 020 samples of 1 c.c. each of the filtered water examined for B. Coli-communis, 34, or 3.3 per cent., gave positive results.

The purity and value of the water may be inferred from the fact that the typhoid fever death rate among the consumers of the filtered water is very low, and that the Eastman Kodak Com-

pany use the water in their delicate photographic work, as do also the New York Central Railroad, the Buffalo, Rochester & Pittsburg Railroad, and many other large consumers, for boiler purposes.

DISCUSSION.

John F. Skinner, Esq.* I visited the pumping station and filter plant of the Rochester and Lake Ontario Water Company, a number of years ago, and found it an extremely interesting plant. There is one matter, however, that I would like to call to Mr. Caird's attention, and ask if it has come to his notice. In Fairport, a village about ten miles from here, one large factory, and I think several others, are supplied with this water; some typhoid has developed in the past in this village, and the doctors, I understand, lay the typhoid to this filtered water, as the patients generally, it is stated, have been employed in places where this water is used. There is a case at the present time, in one of the hospitals in this city, coming from Fairport, and it is alleged to have been due to this water. I would like to ask Mr. Caird what he has to say about it.

Mr. Caird. I might say that about two years ago I came here and investigated some cases of typhoid fever which originated at Fairport, as I understood. Of course we supply other villages beside Fairport, but we found no typhoid fever in the other places. They get the same water, and I felt that if the typhoid was due to the water it would have shown up all along the line. As you know, there is a long line of pipe, and there are several fair-sized communities which receive this water. Typhoid fever is a very hard thing to trace to its origin, particularly when we have only one case. Then again, it is just the close of the vacation time now, when we generally expect typhoid fever will develop. I have not heard anything about this last case which the gentleman speaks of, and of course know nothing about its history. One needs to have a pretty full history of a case before deciding its source, for if there is but one case there is very little to work on.

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* Assistant City Engineer, Rochester, N. Y.

Dr. Roby.* If any of you have attempted to trace an epidemic of typhoid, or even a few cases, you know how difficult it is to do it. The patients themselves are very ignorant about the cause of their disease, and they most always think it is due to the plumbing or to anything rather than the real cause. I was in Lockport, the other day, visiting a boy who had typhoid, and I think I asked him the question seven times before I could finally get out of him that he had been on a farm before the two weeks' time after which he should have come down with the fever. For six times he denied absolutely that he had been out of Lockport, but the seventh time he acknowledged he had been on this farm.

As Mr. Caird just said, if this water carried the typhoid, we ought to find it all along the line. There has not been a case, — and I have looked up, I think, every single reported case which has occurred in Rochester in the last fourteen months, traceable to Ontario water. I will not say anything about Fairport except that if cases have occurred in Fairport, they ought to have occurred in Brighton (part of Rochester) and in the other communities which use the water, if the Fairport cases were due to it. It is impossible to imagine that they would all be located in one town. I am very positive there hasn't been any case in Rochester which could be traced to Ontario water.

We have a very interesting epidemic of typhoid at this moment. There is a bay down here on the lake shore, and dotted all around this bay are a lot of summer resorts. We have had, I suppose, fifty cases of typhoid fever reported since the 1st of July. Every single case which has been reported, with the exception of about four or five, have been to some other place. For example, one case was infected in Pulaski, another case in Erie, and other cases in Buffalo, and so on, until you have a residual of about thirty cases, and almost every one of those thirty cases within two weeks previous to the time when they came down — that is, the time within which the disease would show itself — had been to this little bay. They had not all been to any one spot on the bay, but some had been to Sea Breeze, and others to other places. My only explanation of the thing is that the bay water itself is infected, but not badly infected, and that in some way or other these

* Of the Health Bureau, Rochester, N. Y.

people got the infection out of the bay. The orphan asylum people went up to the bay with ninety children, on the 3d of August, and on the 17th of August the first and only case came down. I could not find that the child had done a single thing different from the rest of the ninety, yet I am quite positive that the child was infected at Sea Breaze, because we have had seven other cases infected at Sea Breeze. So far as the filtered water is concerned, I am perfectly satisfied that there never has been a case of typhoid traced to it.

Mr. Caird. I might state, in connection with the examination of the water, that at times we are using hypochlorite, and we see bacterial plates which remain sterile. I do not believe in a hundred per cent. removal of bacteria, and if the plates are sterile we record at least one per cubic centimeter. Of course a cubic centimeter is a pretty small quantity to examine, and we don't want to say that the filters remove one hundred per cent., and so we put down at least one for every sterile plate. The bacteria in the filtered water during the last three or four months averaged two or three per cubic centimeter.

Mr. W. C. Hawley.* There is one thing in Mr. Caird's paper which struck me particularly. I understood him to say that the floating of that partition baffle wall had no injurious effect upon the operation of the sedimentation basin. Is that correct?

Mr. Caird. That is correct. Our bacterial average remained practically the same.

Mr. Hawley. That is very interesting and very instructive. About eighteen months ago we started to construct a mechanical filter plant. One of the important adjuncts to that plant were sedimentation basins. We asked for proposals from various manufacturers of filter plants, simply giving them our conditions and asking for certain results from the plant, which they might design themselves. Each of the plans which were submitted had elaborate schemes of baffles in the sedimentation basins. We objected to those on the ground that there were more or less dead spaces where the water would stand, and there would be places where the velocity would be considerable. We finally, under the advice of our consulting engineer, did away with all the baffles

* Engineer and Superintendent Pennsylvania Water Company, Wilkinsburg, Pa.

except one midway in the sedimentation basin at right angles to the direction of flow, and so far our results are all that we would expect. The two sedimentation basins are each about 60 ft. wide, 150 ft. long, and about 20 ft. deep. I believe that this matter of baffling has been overdone, and this is confirmed by Mr. Caird's experience.

The President. I should like to ask Dr. Roby if at these resorts on the bay, which he spoke of, they drink the bay water.

Dr. Roby. No, they do not. That is the only explanation I can give why the cases have not been widespread. If there was a well which was infected, which was in common use, it seems to me that we would have very much more typhoid. I may be wrong about it, of course, but the only way I can figure it is that either a few people have gone in bathing in the bay itself and have swallowed water accidentally, or a milk can has been washed in the bay water and one or two typhoid organisms have been left in the can, and they have grown in the milk, and some particular person has happened to get the milk, or something of that sort. People very seldom use the bay water; they use spring water. The only thing which was in common, at these different points on the bay, in all the cases, was the bay water; and that is why I thought it must be the bay water. All the cesspools drain right into the bay, and besides that, the bay has a drainage area up through the country. Last year we had no cases from the bay, but it seems that some typhoid carrier has gotten the typhoid organisms into the bay water this year, when they didn't last year.

Mr. Emil Kuichling.* I should like to inquire of the doctor if flies might not have played a very important rôle in these cases of which he speaks. Every one who has ever seen a children's picnic knows that there is ample oportunity for that kind of infection, as the places where the little ones seek relief in the brush are usually not far from those where food is served; therefore the probability that the food was infected by flies is a good deal stronger than that this large body of water became infected from any point on the watershed.

Much is said about water carrying typhoid fever germs to great distances, and it is very convenient to attribute an outbreak of

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fever to infected water. We should consider, however, that as water-works engineers, we have the same right that medical men exercise when they step over into the domain of some other profession and say, "Oh, you are all wrong; you must accept our standards; we are a great deal better able to judge of this than you are." Turn about is fair play, and I only suggest that there are limitations in medical and sanitary science, just as there are limitations in chemical and mechanical science.

It is therefore necessary to eliminate scrupulously all other possible sources of infection before fixing the blame upon one particular source. If there is anything in the fly theory, surely flies are very liable to have caused the trouble at the picnics mentioned.

Mr. Caird. I might add that I had an interesting experience last summer. Twenty-three cases of typhoid fever came up in a certain place within a week or ten days. Of course, as usual, the water supply was blamed. The doctors had it all fixed, only they didn't have any history of the cases. The first thing I did was to get the history. I found that every one of these persons had been camping up the river and that they were all in the habit of going into the river to bathe. Ten miles up the river there is a city of 18 000 inhabitants, and I found 12 cases of typhoid fever up there. Of course the sewage from that city went into the river. Upon investigation I did not find one of those cases where the family admitted, or the patient admitted, that the physician had given any instructions as to what to do with the stools, and so they were just dumped into the toilet and washed right down, without any germicide being used at all, and came down the river where these men went in swimming. That illustrates the importance of the treatment of the discharges from typhoid patients, for if they are put into the sewer they are liable to cause trouble unless they have been treated, and treated properly.

Mr. R. W. Post. There is an outhouse within fifty feet or so of one of the main picnic tables at Sea Breeze.

Dr. Roby. In answer to Mr. Kuichling, I will say that I am not by any means sure of my conclusions, and I did not mean to say that I was sure. But I think the chances are that the source of contagion was the bay water, because it seems to me difficult to imagine that all these places, which are some distance apart,

could be infected, for instance, by flies from a common source. I doubt whether flies would get as far as from Sea Breeze across the bay and to these other places. Of course they might, — I suppose it is within the range of possibility, — but I doubt it; and the only thing in common is the bay water. I have looked up the milk supply, and it is different in the different places. The water that they drink is different at all these different places, and the only thing in common is the bay water itself. That is the reason I arrived at my conclusion, but perhaps it is a wrong one.

Mr. Caird. May I ask the doctor if he finds that people when they do have a case of typhoid pay much attention to the discharges of the patient.

Dr. Roby. I think they do, but I don't believe you can ever control it in that way, for this reason: the patient may not go to a physician for a long time, and it may take the physician quite a long time to make his diagnosis.

Mr. Leonard Metcalf. I should like to ask Mr. Hawley to say one word with reference to the method of introducing the water into their sedimentation basin and taking it off, for it seems to me that is important as well as the method of baffling.

Mr. Hawley. The water is introduced at one end of each sedimentation basin through a number of 8-in. vertical pipes, which discharge about a foot above the surface of the water on to a floating plank platform. There is a strip of 2- by 4-in. timber on the side of the platform towards the basin. The water flows back toward the end of the basin, thus disturbing the water in the basin as little as possible. It then flows to the other end of the sedimentation basin, passing under the reinforced concrete baffle wall. The water has to dip down under and come up the other side, and then is taken out at the other end of the basin into a trough through a number of rectangular holes about eight inches square, placed all along the trough for the whole width of the basin and about a foot below the surface of the water.

Dr. J. Roby (*by letter*). Since the above report was made, it has been discovered that the domestic water supply of Rochester furnished by Hemlock Lake has been contaminated over a certain section of the city. There are two systems in use here: the Hemlock domestic service, depending on gravity for its force and usually

having a head of about 58 lb.; and the Holley system, taking water from the river for fire purposes. In some way or other the gate connecting these two services was left open and consequently the river water was pumped into the Holley mains. When this was discovered, it was found that apparently only that part of the city lying north of Allen Street and west of the river (about one fourth of the area of the city) showed contamination of the water. None of this water showed contamination by colon bacilli when tested, but as it has been going on all summer — and as some twenty cases of typhoid have developed right in this region and explainable by no other cause — it seems safe to say that at times this water contained typhoid bacilli.

Some of the cases previously ascribed by me to contamination at the bay were undoubtedly infected by this water, but I am inclined to think that there is, or was, contamination of the bay water also. As this section of the city has a population of some 40 000 to 50 000 people, it seems also evident that a large body of water may be contaminated in some spots and not in others. In fact, it seems to me highly probable that a mass of fecal material containing typhoid bacilli might remain undissolved for some time and only infect a few cubic feet of water in its immediate vicinity. Much further study will be necessary in this case; but it seems to me now that these are safe conclusions. The typhoid in Rochester this summer has come from four sources:

1. Those evidently infected out of town.

2. Those who did not live in the suspected area but had been to the bay, and were probably infected by bay water.

3. Those who had not been out of the city at all but who certainly drank the suspected water.

4. Those infected by contact with other cases, as nurses at hospitals.

STEEL PIPES FOR WATER WORKS.

BY E. KUICHLING, C.E.

[*Read September 22, 1910.*]

The subject of steel pipes for water works is attended with so many theoretical complexities that it becomes necessary to be governed largely by the results of the closest observation of such structures in as many different localities as possible.

The chief reason for this empiricism lies in our lack of exact knowledge relating, firstly, to the chemical composition of the metal and its durability when placed in various kinds of soils, and, secondly, to the magnitude of the external forces which act on the pipe after being laid and placed in service. Although much has been printed in regard to these features, there is still room for extended scientific investigation in consequence of important contradictory evidence on vital points, and it is the purpose of the writer to bring some of these to your notice.

Steel pipes are of quite modern origin, as the use of soft steel for making boilers and tubes began in this country only about 30 years ago. Previous to that time wrought iron was generally employed for these purposes, but unfortunately its use for making large pipes for the conveyance of water and sewage was very limited, owing doubtless to its greater liability to corrosion than cast iron. Prior to 1870 it had been adopted for permanent works in a number of places where the liquid was carried under high pressure, and also where rigid foundations could not be secured readily, as in deep valleys, river and canal crossings, bogs, etc.; and in these cases efforts were made to provide the wrought iron with protective coatings of various character. Of its use for temporary construction, no mention need here be made.

With the growth of municipalities and the corresponding development of public water supplies, it gradually became necessary to make pipes of considerably larger size than formerly. To meet this demand, cast-iron pipes having a diameter of 6 feet were produced in a few foundries, but it was soon found that their strength was inadequate for ordinary service, and if made sufficiently thick

their cost would be much more than that of a suitable riveted wrought-iron pipe. Equality of cost for equal strength was also found to occur at diameters of from 2 to 4 feet, depending on the respective market prices of the two metals, even if the acknowledged greater durability of cast iron was taken into consideration liberally.

Although the advantages of large wrought-iron pipes over those of cast iron, from the standpoints of economy and original strength, were early recognized, yet the lack of knowledge of trustworthy means of preventing corrosion was the principal obstacle to their general use. A great number of preservative coatings and processes were devised, but none of them seems to have been entirely satisfactory, and for this reason cast-iron pipes were generally preferred by hydraulic engineers in cases where the required diameter was moderate and the utmost economy was not imperative. Under other conditions an astonishing number of large conduits have been built during the past 40 years of wrought iron and soft steel plates, and it becomes of great interest to learn something of their present condition.

A long list of such conduits is here omitted to save time and space, and of their condition comparatively little has come to the writer's knowledge, except that none appears to have been completely destroyed by corrosion. More or less damage from this cause, however, has been reported in a few cases, and particularly where the metal was steel. The old wrought-iron pipes seem to have given relatively little trouble, and for this reason, as well as from many similar observations in various other metallic structures, the opinion that wrought-iron possesses inherently a much greater resistance to rusting than soft steel is rapidly growing, notwithstanding that numerous experiments to the contrary have been cited in many papers and treatises written by eminent modern metallurgists.

In support of this opinion, the writer ventures to cite a few experiences. For reasons of economy in the construction of the original water works of the city of Rochester, N. Y., it became necessary during the years 1873–5 to make use of a large quantity of 36-inch and 24-inch riveted wrought-iron pipe, ranging in thickness from $\frac{1}{4}$ inch to a little more than $\frac{1}{8}$ inch. Much care was

taken to provide it with a thick bituminous coating; but in the course of transportation this coating suffered considerable damage, which was sought to be repaired in the field. In 9.62 miles of 36-inch pipe, $\frac{3}{16}$ inch thick, no perforation of the sheets by rusting occurred until 1894, when 26 small holes were plugged, several holes being found occasionally in a single plate. In 1896, 18 more holes were plugged under like circumstances; in 1899 and 1900, 10 additional holes appeared, and since the latter year no more have been reported; total in 36 years, 56 small holes, none more than $\frac{1}{4}$ inch in diameter, and all easily stopped without interrupting the flow through the pipe; probable number of damaged plates or sheets, 25 or 30; total number of plates used in the line, about 11 300; pipe laid mostly in clayey soil. The coating was a mixture in nearly equal proportions of refined Trinidad asphalt and coal-tar pitch.

In 2.93 miles of 24-inch pipe of the same conduit, with thicknesses of $\frac{3}{16}$ and $\frac{1}{4}$ inch, only a very few perforations by rust have been reported as occurring in 1894. The most interesting case, however, is that of the 24-inch riveted wrought-iron feed pipe of the Holly direct pressure system in the same city, which was laid in 1874 for the purpose of carrying an alternate supply of impure river water to the pumping station. Its length is about 3 300 feet, and its thickness is a little more than $\frac{1}{8}$ inch. Like the aforesaid conduit, it was protected by a bituminous coating. The water pressure is insignificant and the supply is utilized during only a few days in each year, when the race, or water-power canal, from which the normal supply to the plant is taken, is emptied for general repairs. During the rest of the time the pipe is empty and drained by a 6-inch blow-off connection into a large sewer. The gases in this sewer are thus afforded access to the interior of the pipe in the vicinity of the blow-off. The street soil in which the pipe is buried for a length of nearly 2 000 feet, is rich in organic matter. Under these unfavorable conditions a long life for this section of the pipe was not expected.

For 25 years no repairs were needed, and little was known of its actual state of preservation. In 1899, however, it was deemed expedient to examine it closely, and the greater part of said length of 2 000 feet was fully exposed. The pipe was then inspected

closely by a number of thoroughly experienced metal workers, and was found to be so little corroded that its contemplated replacement with cast-iron pipe was regarded as unnecessary. It was accordingly left in place after applying a fresh coating of hot asphalt and coal-tar pitch to the exposed external surface, and has remained in good service up to the present time, with a life of 36 years.

In 1873 the writer investigated the condition of a number of $\frac{3}{4}$-inch and 1-inch wrought-iron gas service pipes in Rochester, which had remained undisturbed in the ground for more than 18 years. None of these pipes had received any preservative coating, and in most cases the exterior surface was then found to be somewhat corroded, but on removing the earthy crusts no deep pittings were observed. Several of them are still in place after a life of at least 55 years, the remainder having been removed when the dwellings were replaced by commercial buildings that needed larger supply pipes. It also is very probable that a search of the records kept by the gas companies of our cities would reveal a multitude of similar instances.

Mention of numerous other observations of like character by the writer is here omitted for lack of space, and in contrast thereto a few of his experiences with soft steel pipes will be cited. The second conduit of the Rochester water works was constructed in 1893–4 in consequence of the insufficiency of the former supply. Its principal feature is a riveted steel pipe 38 inches in diameter, nearly 26 miles long, and ranging in thickness from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch. Three different kinds of protective coating were applied to the metal in different sections of the work. The first one was a Californian asphalt or maltha, which appeared to be satisfactory and had been used very successfully in other localities, but soon showed signs of disintegration here; the second was a mixture of refined Trinidad asphalt and coal-tar pitch, like that which had been used on the old wrought-iron conduit; and the third was the baked or "japan" coating which had meanwhile been devised by Prof. A. H. Sabin.

The writer ventures to assert that the utmost care was taken by all of the city's employees to secure the best quality of metal and coating, as well as good workmanship in the field; furthermore,

there was no indication, on the part of any of the contractors, of an intention to slight any part of the work or to use improper material or mixtures. The steel may therefore be regarded as representing the best metallurgical skill and experience available at that time, which was fully thirteen years after the art of steel making had been developed in this country to such an extent as to supplant the production of puddled wrought-iron on a large scale. The history of this conduit, however, shows that in spite of all the care that had been expended on its construction, serious corrosion of the metal began to appear in 1901, or only seven years after its completion. Perforation by rusting was then discovered in a number of plates at seven different localities in the two sections of pipe which had been coated with Californian and Trinidad asphalt. Examinations were also made in the same year at 25 other localities in the entire route where leakage had not yet appeared, and in some of the excavations more or less pitting of the steel was seen. The soil was mostly a stiff red and blue clay.

A careful study of the problem was made by Prof. F. L. Kortright, of Morgantown, W. Va., during 1901 and 1902. No corrosive acids or gases were found in considerable quantity in the soils and ground water, and the cause of the rusting was ascribed mainly to the action of mill scale, oxygen, and free carbonic acid, at points where the coating was defective. To remedy the trouble, he advised a thorough scraping of the metal and the application of two coats of mixed red lead and graphite paint, followed by two additional coats of mineral rubber paint or Truscon Special paint. The practice is to expose the pipe fully wherever extensive corrosion is discovered, scrape off the defective coating, and apply the said four coats of paints mentioned to the entire surface; the excavation and recoating process are then continued in both directions until all sign of rusting disappears.

Up to the end of 1907, a total of 205 perforations of the steel by corrosion were found and repaired. All of these but one were in plates $\frac{1}{4}$-inch thick, and it is interesting to note that only about 16 occurred in the plates made by the Pennsylvania Steel Company and protected by the Sabin coating, while the remainder occurred in the plates made by the Carnegie Steel Company and protected with Californian and Trinidad asphaltic coating. These figures,

however, do not indicate correctly the respective merits of the two metals, as the length of pipe made of Carnegie Steel Company plates $\frac{1}{4}$ inch thick is somewhat greater than that made of Pennsylvania Steel Company plates of the same thickness; but it is certain that the latter plates exhibit a much greater resistance to rusting than the former.

Both metals were prepared by the open-hearth process from the same specification, which required the impurities to be limited to the following percentages: Sulphur and phosphorus, each 0.06; manganese, 0.60. The physical tests called for a tensile strength ranging from 55 000 to 65 000 pounds per square inch, with an elastic limit of 30 000 pounds, and an elongation of 22.5 per cent. in a length of 8 inches; also for various tests as to cold-bending, punching, drifting, and forging. The inspectors reported full compliance with all of these requirements, but it may be of interest to remark that the analyses of the Pennsylvania Steel Company's metal usually exhibited a considerably smaller percentage of manganese than was contained in the product of the Carnegie Steel Company. In the light of recent investigations on corrosion, this fact may account for the much larger number of perforations that have appeared in the latter metal.

The experience with the riveted steel conduit that supplies drinking water to the city of Portland, Ore., is very similar. This conduit is about 24 miles long, and varies in diameter from 42 to 33 inches, with plate thicknesses ranging from $\frac{3}{8}$ inch to $\frac{1}{5}$ inch. There are also several lines of smaller riveted steel distributing pipe, from 30 to 18 inches in diameter and from $\frac{1}{4}$ inch to $\frac{1}{6}$ inch thick. All of these pipes were made of eastern steel plates in 1895–6, under the same general specifications that were used for the Rochester conduit, and were well coated with Californian asphalt or maltha. After nearly nine years, leakage due to rust perforations appeared in a number of 35-inch conduit plates $\frac{1}{5}$ inch thick, laid in clayey soil. On exposing the pipe for repairs, an extensive pitting of the metal was found, which led to an examination thereof in 1905 at many other points in the route, and the discovery of more damage of like character. Since that time perforations have occurred in plates $\frac{1}{4}$ inch thick.

In his report on the subject, dated November 27, 1905, the

engineer of the Portland Water Board, Mr. D. D. Clarke, states that the severest corrosion occurred where the pipe was laid in clay, and that little injury from rust was observed in sandy and gravelly ground. This implies that the moisture in the clay may be the principal cause of the active corrosion, but as no chemical examination of the clay was made at the time, it may yet be found that the composition of the metal is more at fault. Mr. Clarke also remarks that in all cases where thin modern riveted conduits have exhibited a long life, the metal was wrought-iron.

Another interesting instance of the early corrosion of steel plates is also afforded by the 48-inch riveted steel force main of the New Bedford, Mass., water-works. The plates were all $\frac{5}{16}$ inch thick, the length of the line is 8.25 miles, the coating was Californian asphalt, and the work was done in 1896. Trouble with electrolysis in the distribution system led to several close examinations of this steel pipe during the past nine years, although no perforations have yet appeared. The investigations made in 1901 showed some external damage by electrolysis at a certain locality. In 1908 and 1909, the interior of the pipe was inspected, and it was found that the asphaltic coating had become very brittle, also that there had been a large increase in the number of tubercles since 1901. The heaviest tuberculation was near the field-made joints, and was more intense on the bottom than upon the sides and top. Beneath the tubercles were pittings, many of which were from 0.075 to 0.095 inch in depth. An abundance of large blisters in the coating was likewise found. These blisters were filled with water, but the metal underneath was free from rust and pits.

In contrast with the preceding cases of rapid corrosion of steel plates, a number of instances might be cited where similar plates have apparently been much more resistant. The most notable one is the 48-inch riveted steel conduit of the city of Newark, N. J., which was constructed in 1890–1, and in which many plates only $\frac{1}{4}$ inch thick were used, the protective coating being Californian asphalt or maltha. This conduit is now 19 years old, and the writer has not learned that any perforations by rusting have yet occurred therein.* In the other cases of which the writer received

* Since the reading of this paper, it has been reported in *Engineering Record* of October 8, 1910, p. 412, that a leak by corrosion occurred in the Newark 48-inch steel conduit in August.

favorable reports, the examinations were not very extensive and the plates were more than $\frac{3}{8}$ inch thick.

It is very evident from the foregoing that the thickness of the metal is a highly important factor in estimating the durability of a water pipe, whether the same be made of wrought-iron or soft steel. The statement is frequently encountered that the rate of corrosion reduces rapidly after a very thin film of metal on the surface has been destroyed by rusting, and that a great many years would be necessary to effect a loss of $\frac{1}{16}$ inch in the thickness of a plate. This may be true if the corrosion is of uniform intensity over the entire surface, but unfortunately, it generally happens that the action is localized so as to produce pits of more or less depth between which the metal retains its original thickness. A thin plate will accordingly give evidence of perforation much sooner than a thicker one, and thus lead to an earlier examination of the condition of the structure.

The development of pits is regarded as proof that the metal is not homogeneous in composition; hence it follows that in dealing with mixtures or alloys, the different ingredients should be diffused as uniformly as possible throughout the entire mass. In the old method of fabricating wrought iron, such diffusion of unavoidable impurities was accomplished by the laborious process of puddling, but in the modern method of making steel, the tendency has been to minimize the work of thoroughly mixing together the various constituents, particularly the manganese, upon which much now appears to depend.

The manganese is added for certain specific purposes, not quantitatively as a rule, but according to the views of the iron-master in charge of the furnace, by throwing lumps of ferro-manganese into the molten metal, either in the furnace or in the ladle into which it has been poured. An intimate mixture or diffusion of the material does not usually take place in this practice, and even when an effort is made to obtain it by pouring the contents of the ladle into another empty one, it still happens that when the molten metal cools, a segregation of the impurities will occur;

1909. The pipe had here been laid in swampy soil, and while repairing said leak an inspection was made of an adjoining steel pipe laid in 1896. This newer conduit was also found to be corroding, but not to the same extent as the older one.

that is to say, the impurities do not remain distributed uniformly or homogeneously through the solidified mass. It must therefore be remembered that the wrought iron and steel usually encountered in engineering work is not a homogeneous pure metal.

The corrosion or decay of iron and steel thus becomes one of the leading questions of the day among engineers. Under the action of natural agencies alone, this decay is often much more rapid than that of wood, while in many other cases it is extremely slow; and on investigating the subject historically, it will be found to be attended with numerous contradictory observations which make its discussion very difficult.

Definition of Terms. It is important to have, in the outset, a clear definition of what is meant by the words *iron* and *steel*. By *iron* the chemist means a pure element of matter, while the metallurgist means thereby a more or less varied mixture of this element with other elements. Absolutely pure iron does not seem to exist in nature, or to be capable of production by the usual processes of manufacture on a commercial scale. As commonly known to mankind, iron is always an impure metal owing to its peculiar property of readily combining with or holding in solid solution nearly all of the other elements. It has also been found that very small quantities of impurity suffice to produce great changes in its physical characteristics, and for this reason experts often scrutinize very closely the hundredth of one per cent. of some of its principal impurities, which are carbon, silicon, sulphur, phosphorus, oxide of iron, and manganese.

By *steel* is meant an alloy or intimate mixture of pure iron with several other elements, the principal of which is carbon, and by varying the proportions a great variety of steels is produced which have widely different physical properties. It is, however, impossible to consider in this paper all kinds of commercial iron and steel, and hence the discussion will be limited to the few varieties alone which are of particular interest to water-works' engineers. These varieties are the cast iron, wrought iron, and mild or soft steel commonly used for making pipes.

Cast Iron. As usually understood, cast iron is not an alloy but an aggregation of chemical and mechanical compounds. It contains more or less of the impurities found in both the ore and

the fuel used in its production. Its principal characteristic, however, is the large percentage of carbon which it holds in chemical and mechanical combination. When used for making water pipes and machinery, its composition is generally within the following percentage limits: Graphitic carbon, 2.50 to 2.90; combined carbon, 0.35 to 0.45; silicon, 1.50 to 2.00; sulphur, 0.07 to 0.10; phosphorus, 0.50 to 0.60; manganese, 0.31 to 0.40. Tensile strength from 12 000 to 21 000 pounds per square inch.

By reducing the graphitic carbon to 1.50–2.00, the silicon to 0.70–1.20, the sulphur to 0.05–0.06, the phosphorus to 0.40–0.50, and increasing the combined carbon to 1.15–1.30 per cent., a much tougher and stronger material will be obtained, as the tensile strength will then rise to 30 000–35 000 pounds per square inch.

Wrought Iron. In the fabrication of wrought iron, most of the impurities of cast iron are eliminated by the agencies of heat and oxidation, so that the final product contains from 98.5 to 99.5 per cent. of pure iron. It is characterized by a much higher melting point than either cast iron or steel (1500 to 1600° Cent. as against 1100 to 1200° Cent. for cast iron, and 1350 to 1450° Cent. for steel) and by its malleability. Its chemical composition is generally within the following percentage limits: Combined carbon, 0.02 to 0.25; silicon, 0.02 to 0.10; sulphur, 0.001 to 0.10; phosphorus, 0.001 to 0.10; manganese, 0.001 to 0.25; slag and oxide, 0.30 to 1.25; pure iron, 98.5 to 99.5. Tensile strength from 40 000 to 50 000 pounds per square inch.

The undesirable impurities are mainly carbon, silicon, sulphur, and phosphorus. Most of these can be removed by prolonging the heating and puddling processes by which the metal is made from molten pig iron; but as these processes are slower and more expensive than those involved in the fabrication of modern soft steel, wrought iron has gradually been supplanted by the cheaper material for most industrial purposes.

Mild Steel. Many varieties of mild steel are made by both Bessemer and open-hearth processes, which differ little in chemical composition from wrought iron, except that they contain no intermixed slag. It is said that carbon is the most important constituent of steel, as it tends to harden the metal and also to increase its tensile strength. These properties, however, are more or less

incompatible with ductility; hence in ordering steel for purposes wherein softness is important, the maximum tensile strength which the metal should have is usually specified.

For the best pipe and boiler work, steel is generally made by the open-hearth process, and its composition lies within the following percentage limits: Combined carbon, 0.10 to 0.20; silicon, 0.005 to 0.010; sulphur, 0.015 to 0.045; phosphorus, 0.015 to 0.030; manganese, 0.30 to 0.50; iron oxide, 0.10 to 0.30; pure iron, 98.5 to 99.5. Tensile strength from 50 000 to 65 000 pounds per square inch.

Of these constituents, carbon and silicon affect the hardness, ductility, and tensile strength; sulphur produces "red-shortness," or interference with welding and rolling; phosphorus produces "cold-shortness," brittleness under sudden shock, and various other undesirable properties; manganese counteracts to some extent the influences of sulphur and phosphorus and causes the metal to aggregate in finer crystals, thereby increasing its elastic limit and ultimate strength.

Until within a very few years, manganese was regarded as a beneficial ingredient and was always added to the molten iron in making mild steel. Recently, however, it has been viewed as the principal cause of the rapid corrosion of soft steel under ordinary conditions of use, and this has led to a further development of the open-hearth process whereby nearly pure iron is produced without adding manganese, and also without much additional cost. This new material has been named "ingot iron," to distinguish it from steel, and a long description of it is given in *Engineering News* of January 6, 1910, pages 6–8 and 16, from which the following brief abstract was prepared.

Ingot Iron. The metallic product called "ingot iron" is made in an open hearth, like mild steel, and differs from the latter in having its contents of carbon, silicon, and manganese reduced to small fractions of the amounts found in ordinary soft steel. Its chemical composition is practically the same as that of the purest commercial wrought iron, and it contains much less impurities than common wrought iron. A typical analysis is as follows: Carbon, 0.02; silicon, trace; sulphur, 0.02; phosphorus, trace; manganese, 0.01; oxide of iron, 0.03; pure iron, 99.92 per cent.

Its tensile strength is from 47 000 to 50 000 pounds per square inch, and it has a remarkably high ductility. Its most interesting quality, however, is an apparently high resistance to corrosion.

The manufacture of this metal was evolved by the American Rolling Mill Company, of Middletown, Ohio, in consequence of the demand for an iron that would not corrode as quickly as ordinary soft steel, and in deference to the opinion expressed lately in numerous quarters that the rapid corrosion of steel is largely due to the presence of manganese. The main features of the process are the long exposure of the molten metal to a temperature of about 1677° Cent., and the addition of small amounts of ferro-silicon and aluminum just before pouring to facilitate the removal of oxygen and other gases from the liquid. It is claimed by the makers that with proper care uniform results are obtained.

With respect to corrosion, the only comparative tests thus far recorded were made with sulphuric acid, and these indicate that the resistance of ingot iron is from 20 to 40 times that of wrought iron, and from 40 to 60 times that of soft steel. There are, however, many uncertainties in such tests, and hence time alone will demonstrate its slow rusting properties. Should these be such as to be only twice the life of structures made from the best soft steel, the new process will rank as the most important innovation in the metallurgy of iron.

Difference in Composition of Wrought Iron and Mild Steel. On comparing the chemical analyses of commercial wrought iron and mild steel, little difference in composition is apparent except in respect to slag and manganese. In steel and ingot iron there is little or no slag, while in wrought iron the percentage of manganese is usually much lower than in steel. There is also little difference in the usual physical properties of the two substances when the compositions are nearly alike. In regard to durability or corrosion, however, the general opinion now seems to be that wrought iron is far superior to mild steel.

Difference in Rate of Corrosion. The difference between the rates of corrosion of wrought iron and steel, as given by numerous authorities, varies greatly. This may be due to the dissimilarity of either the forces tending to produce rust, or the composition of the two metals in the observed cases; but from the

evidence now available, it seems that under like surroundings comparatively small differences in chemical composition are able to produce relatively large differences in the rate of corrosion. The observations and tests heretofore made embrace many different conditions of exposure, such as waters and soils heavily charged with various mineral and organic acids, bases, and salts, different corrosive gases, etc.; but as a recital of all these results is here impracticable, only those cases will be considered which deal with the conveyance of potable water and the burial of pipes in the earth usually found in streets, roads, forests, and fields.

Ancient Samples of Wrought Iron. To indicate in striking manner the actual differences in rate of corrosion of samples of old wrought iron and mild steel of very recent production, a few facts may be cited that properly belong in the history of iron.

So far as the writer has been able to ascertain, the oldest specimen of wrought iron in the world is now preserved in the British Museum, along with the details of its discovery. It was removed in 1838 by Col. Howard Vyse and Mr. J. R. Hill from an inner mortar joint of the stonework near the mouth of the southern narrow air channel of the great pyramid of Cheops at Gizeh, near Memphis in lower Egypt. Judging from its position and size, it is a portion of a mason's tool broken off accidentally and left in the joint when the structure was in process of construction. According to the surmises of archeologists, this pyramid was built about 3000 years B.C., so that the fragment was presumably over 4800 years old when discovered.

This specimen of iron is about 4 inches long by 2 inches wide and $\frac{1}{8}$ inch thick. It exhibits the marks of some corrosion, but was evidently protected to some extent by the mortar, of whose composition nothing definite is recorded except that it was probably calcareous and more or less permeable to air. An analysis of a small quantity of the metal showed that it was evidently a tough wrought iron.

In 1870 Mr. G. Belzoni found in an excavation in the soil underneath a sphinx at Karnak, near Thebes in upper Egypt, a part of a wrought-iron sickle. He and other archeologists believe that this specimen must have been left in the ground long before the Persian invasion in the sixth century B.C. It was quite rusty when exhumed,

but, on being cleaned, plenty of sound metal was left to exhibit clearly its character and the marks of forging. No other definite age has been assigned to this interesting object.

It may also be stated that many other specimens of ancient wrought iron have been found in the numerous excavations made in Egypt, and are now preserved in various Egyptian and European museums. They are all of the utmost interest, as the ruins of that land are generally regarded as the oldest relics of the human race.

In 1846 and later years, Layard made his famous excavations in ancient Assyria and Chaldea, at the sites of the old cities of Babylon and Nineveh. At the former he found only a few wrought-iron finger rings, but in the latter many iron objects, such as daggers, swords, shields, spear and arrow heads, were brought to light. At Calah, he exhumed a large quantity of iron armor scales from 2 to 3 inches in length, as well as some iron helmets. It may be noted that most of the objects were very rusty when discovered, and that some fell to pieces soon after they were exposed to the air, so that only a few of them could be saved and placed in the British Museum. The period in which they were made is estimated as being between 1500 and 2000 years B.C.

Extensive French excavations of an ancient Assyrian palace at Khorsabad were also made in 1866 by Victor Place. Here a great collection of rough implements or billets of wrought iron was found in a buried chamber 16.4 feet long, 8.5 feet wide, and 4.6 feet high, the weight of the metal being about 160 tons. Unfortunately, the most of this collection was lost by shipwreck in the course of transportation to Paris. These excavations also disclosed a number of iron rings and staples still attached to a long wall, links of chains, bits for horses, etc. The chemical analysis of samples of all this metal showed that it was good wrought iron. Its age is believed to date from 1200 to 1500 years B.C.

In his excavations of ancient Troy and Mycenæ in Asia Minor and Greece respectively, during the period 1870–90, Schliemann found a number of wrought-iron objects, such as keys and knives, far below the surface of the ground, and which were still in a relatively good state of preservation. One of these specimens was found in the fourth distinct stratum of Trojan ruins below the surface, or the one following the city which Homer made famous.

Schliemann estimated that the latter was destroyed by the Greeks from 1400 to 1500 years B.C., while Gladstone considered that the event took place about 1307 B.C. The specimens of iron found at Mycenæ are regarded by Schliemann as dating from about 500 B.C.

Returning to Egypt, a very interesting fragment of wrought iron was found early in 1880 at Alexandria under the base of the obelisk which is now standing in Central Park in the city of New York. This fragment was discovered when the monolith was lifted up preparatory to removal, and it was exhibited at a meeting of the American Institute of Mining Engineers on February 17, 1880. On being analyzed it was found to have the following percentage composition: Carbon, 0.521; silicon, 0.017; sulphur, 0.009; phosphorus, 0.048; manganese, 0.116; nickel, cobalt, and copper together, 0.181; lime and slag, 0.370; pure iron, 98.738; total, 100.00 per cent. Tested by tension, its strength was 54 500 pounds per square inch, with an elongation of 14 per cent., thus showing that the metal was of good quality. Its age is conjectured to be about two thousand years.

At the mosque of Kuttub Shah, at Delhi, India, there is still standing a wrought-iron column which is described by Col. A. Cunningham in the archeological report to the government of India for 1861–2 as follows:

"The Delhi pillar is a solid shaft upwards of 16 inches in diameter and about 50 feet high. . . . Its height above ground is 22 feet, consisting of 3.5 feet roughly cylindrical lower portion, 15.0 feet smooth shaft, and 3.5 feet ornamental capital. It extends underground considerably further than above ground, as a recent excavation was carried down to 26 feet without reaching the foundation on which it rests. The lower diameter of the shaft is 16.4 inches and the upper diameter is 12.05 inches. It contains about 80 cubic feet of metal and weighs upwards of 17 tons."

An inscription on this column has led some antiquarians to think that it was erected in the third or fourth century of our own era, but others have construed the language to indicate that it was made about 900 years B.C. A small sample of the metal was analyzed by Dr. Percy, the eminent English metallurgist, who declared it to be soft wrought iron. The column is entirely free from corrosion, and many who have examined it closely in recent years have ex-

pressed the opinion that, on its completion, it must have been subjected to a process similar to that invented a few decades ago by Messrs. Bower and Barff.

Colonel Pearse, of the Indian army, examined numerous tumuli or sepulchers in India, and found therein many ancient iron and steel tools which are supposed to have been made at least 1500 years B.C. Iron beams have also been found in a number of old Indian temples.

Several objects of wrought iron were found in ancient Etruscan tombs at Cervetri, Perusia, Vulci, and Cortona, in Italy. In 1823 Avvolta discovered a grave at Corneto which led to finding, near by, a large cemetery of the old Tarquins. He states that on excavating a portion of this cemetery he found several graves containing iron spear heads and portions of iron armor, but that these objects usually began to crumble soon after being exposed. Dennis made similar observations at Vulci. Many of the objects thus found are now preserved in various Roman museums.

It may also be noted in this connection that on August 21, 1910, the Associated Press dispatches of New York contained an account of the newest discovery made by Professor Dall' Ossa in the excavation of an ancient necropolis near Civita Castellana in Italy. This locality is rich in remains of Etruscan and other prehistoric civilizations. Two tombs of Amazons were found, each of which contained not only the human female skeleton, but also the remains of a war chariot and yoke decorated with bronze and iron, as well as many iron pins and a dagger. From the jewelry and pottery likewise found therein, the discoverer believes that these tombs date from at least the eighth century B.C. Special mention is made in the account that much dampness and earth had penetrated into these sepulchers, but it is evident that their action did not cause the iron to disappear completely after so long a time.

Passing to the western hemisphere for very old specimens, it is stated that in excavating some of the ancient artificial mounds in Ohio, a variety of wrought-iron objects were found in a fair state of preservation. No definite period has yet been assigned to the construction of these mounds, which have been in existence longer than the survival of any reliable tradition relating to them among the Indians.

For samples of iron and steel made since the beginning of our own era, and which have withstood the effects of centuries of burial in the ground, we need only refer to the catalogues of the large museums of the principal cities of Europe. In these will be found many specimens of iron tools and weapons made by the Romans and later by the so-called "barbarian" inhabitants of European countries. Numerous iron relics of Middle Ages are also preserved therein, as well as specimens of more recent production.

In some of the museums of the United States may be found a variety of wrought-iron objects, dating from the Indian and Revolutionary wars, that were excavated from the ground after burial for a century or more. Unfortunately such comparatively modern relics are of little popular interest, and hence no concerted effort has been made for their preservation. This remark is also applicable to specimens of wrought iron and steel placed in the ground only about fifty years ago.

The foregoing few citations will suffice to show that apparently unprotected wrought iron and steel of certain indefinite chemical composition has been able to withstand the corrosion induced by burial in the soil for a great many years, and even centuries in some cases; and in contrast thereto we have the evidence of many recent observations and experiments that the soft steel which has taken the place of wrought iron for the past thirty years is far less durable under the same conditions of exposure to corroding influences. To describe these experiments would require much more time than is now available, especially as their results are doubtless familiar to all present.

It may be urged that in most, if not all, of the recorded cases of exhumation of wrought-iron objects, after long burial, the metal was effectively protected by being excluded from exposure to air, water, and various acids. This may be true to a limited extent, but in view of the difficulty of attaining such exclusion artificially for long periods of time by means of cements, mortars, and natural building materials, it is reasonable to assume that for the greater portion of their imprisonment these iron objects came into occasional contact with at least small quantities of oxygen, moisture, and carbonic acid, all of which are usually present in soils capable

of supporting vegetation. The conclusion therefore follows that the apparent resistance to corrosion in these cases is due to either some peculiar mode of treating the surface of the metal, or to some peculiarity of chemical composition. In either event, a thorough knowledge of the facts would be of immense value.

As the matter now stands, little will be gained by comparing chemical analyses, owing to differences of method in carrying out the same, and also to the fact that small variations in the amount of impurities contained in the samples often seem to exert a powerful influence on the degree of resistance to corrosion. If, however, the analyses were all made by the same method and care, the effect of each added quantity of impurity might be ascertained, so that the proper composition of a rust-resistant iron or soft steel could be prescribed in a specification. Under present conditions this cannot be done with much certainty of securing the desired result.

The statement has often been made that the superior resistance to corrosion exhibited by some brands of wrought iron is due to the small percentage of slag and cinder or iron oxide always found therein. Microscopical examination, however, does not justify this conclusion, as these impurities are usually found to lie in definite streaks or lines in the metal; neither is there any evidence to show that the fibers of wrought iron are enclosed by cinder or slag. On the other hand, many impure wrought irons are not at all resistant to corrosion, so that the admixture of the impurities mentioned is by no means a safeguard against serious damage by rust.

The latest view on this subject is that the purer the iron the less the tendency to the dangerous pitting or localized corrosion which is so often exhibited in very impure wrought iron and carelessly made steel. It is based on many observations of the much greater durability of puddled wrought iron over soft steel under the same condition of exposure, and also on the new electrolytic theory of corrosion, as advanced by Messrs. W. R. Whitney, A. S. Cushman, and W. H. Walker. It has also been adopted by a few manufacturers in our country, who have succeeded in developing the open-hearth process until they were able to produce in regular practice and without undue extra cost, a metal which is 99.94 per cent. pure iron, and which exhibits far more resistance to corrosion, under accelerated tests, than the best quality of soft steel.

Theories of Corrosion. In their newest treatises on the corrosion of iron and steel, published this year, Messrs. A. S. Cushman, H. A. Gardner, and Alfred Sang state that there are now three well-recognized theories to account for the corrosion of iron. These theories overlap to some extent, but involve distinctly different reactions. They are called the carbonic acid, the hydrogen peroxide, and the electrolytic theories.

The first theory has been under consideration for more than forty years, and is based on the cyclical action of three factors, viz., an acid, water, and oxygen. Rusting is always started by an acid, and even the weak carbonic acid, which is so widely distributed in nature, is strong enough for the purpose. The acid changes a portion of the pure metal to a ferrous salt with the evolution of hydrogen. Water and oxygen now act upon the ferrous salt so as to form ferric hydroxide and liberate the acid, which attacks another portion of the iron; and so on indefinitely until the supply of oxygen, water, or iron gives out. If the acid is not present, the iron will not rust, nor will it do so in the absence of either of the two other factors. Recently, however, experimental evidence has been given to show that rusting takes place rapidly in the presence of water and oxygen alone.

The second, or hydrogen peroxide theory, was advanced by Traube more than twenty years ago, but has not been extensively followed. It assumes the presence of only iron, oxygen, and water. The oxygen is assumed to act in two portions, one of which attacks the iron and forms unstable ferrous oxide, while the other combines with the water and forms hydrogen peroxide. These two products then combine to form stable ferric hydroxide, leaving an excess of hydrogen peroxide to attack a new quantity of ferrous oxide. The theory has been strongly criticised within the past six years as not being in accordance with careful experimental tests.

The third, or electrolytic theory, appears to have had its inception in the researches of Dr. W. R. Whitney, published in the Journal of the American Chemical Society for 1903 (Vol. XXV, p. 394). It was then developed so skillfully by Dr. A. S. Cushman, of Washington, and Prof. W. H. Walker, of Boston, that it has now been generally adopted by chemists in this country and abroad. It rests on the modern principle of physical chemistry, that all

reactions taking place in the wet way are attended with certain readjustments of the electrical states of the reacting ions; or, expressed in another way, when two substances of different polarity are immersed in a suitable liquid medium containing free ions of matter, an electric current is set up, and the substance from which the current flows tends to dissolve. It thus assumes that before iron can oxidize in the wet way, it must first pass into solution as ferrous ions.

Cushman further explains the process of rusting as follows:

"When a strip of metallic iron is placed in a solution of copper sulphate, iron passes into solution and copper is deposited, this change being accompanied by a transfer of electrical charge from the ions of copper to those of iron. Hydrogen acts as a metal and is electrolytically classed with copper in relation to iron. If, therefore, we immerse a strip of iron in a solution containing hydrogen ions, an exactly similar reaction will take place; that is to say, iron will go into solution and hydrogen will pass from the electrically charged or ionic state to the atomic or gaseous condition. In such a system the solution of the iron, and, therefore, its subsequent oxidation, must be accompanied by a separation or setting free of hydrogen. It is very well known that solutions of ferrous salts as well as freshly precipitated ferrous hydroxide, are rapidly oxidized by the free oxygen of the air to the ferric condition, so that if the electrolytic theory can account for the original solution of the iron, the explanation of rusting becomes exceedingly simple."

The theory also rests on the laboratory demonstration that a small proportion of iron can pass into solution in ionic form in pure water, and that the latter always contains some free hydrogen ions; hence it follows that neither oxygen nor carbonic acid is needed to assist the action of pure water in starting the formation of rust. The hydrogen ions seem to act as an exciter in starting the reaction by creating a galvanic current, which is carried from one point on the iron to the water by the escaping iron ions, and from the water back again to the iron by the separating hydrogen ions, this process being continued indefinitely. Furthermore, if the metal contains impurities, like manganese, that are electrically positive to the iron, this galvanic action is intensified. Much more might be said on the subject, but as the time therefor is not now available, such additional explanations must be sought in Dr. Cushman's new book.

The corrosion of iron in water has also been discussed in a very instructive manner by Mr. Geo. W. Fuller, in the issue of *Engineering Record* for April 23, 1910; and as this paper contains many useful data, the following brief abstracts therefrom may be of interest.

Iron will corrode more rapidly in waters containing dissolved oxygen and compounds of an acid nature, even though very weak, such as carbonic acid. All surface, filtered, and ground waters contain more or less dissolved oxygen and carbonic acid, besides a variety of other substances of both mineral and organic nature. The oxygen is generally absorbed from the atmosphere either above or below the surface of the ground, and in the case of surface waters a part of the oxygen is sometimes supplied by certain aquatic plants. The quantity of oxygen thus held in solution varies with the temperature, the degree of organic impurity, and the agitation of the water. When fully saturated, the range in pure water is from 14.70 parts of oxygen by weight per million at 0° Cent. to 7.60 parts at 30° Cent., so that the quantity changes considerably in the different seasons. It must also be remembered that in the case of polluted water the bacteria often consume a large proportion of this dissolved oxygen in their action on carbonaceous organic matter, and liberate a corresponding quantity of carbonic acid which goes into solution.

From numerous analyses of the water in various large rivers, it appears that in winter the quantity of dissolved oxygen is from 9 to 12 parts per million, while in summer it is from 5.6 to 7.5 parts. Ground waters, on the other hand, usually contain much less oxygen in solution than the surface waters, presumably because the bacteria in the porous earth, through which the water passes downward to the plane of saturation in the subsoil, abstract a large percentage of this gas. Available analyses show a wide range in this respect, the variation being from nearly the aforesaid saturation limits to only 10 per cent. thereof, with an average of about 50 per cent.

At already stated, free carbonic acid is derived in part from the air, but mostly from bacterial action on the organic matter contained in either the soil or the water. Surface waters usually hold in solution much less carbonic acid than ground waters, the

contents of the former being from a very minute quantity to 15 parts by weight per million, while the latter may contain from 3 to 25 parts. In some mineral spring waters the proportion is very much higher, even attaining the stage of effervescence. The presence of this gas increases the solvent powers of the water, and enables it to dissolve carbonate of lime and magnesia quite freely. One gallon of pure water will only dissolve two or three grains of these carbonates, but when it becomes strongly charged with carbonic acid, it may dissolve twenty or more grains.

Natural waters also often contain certain other acids and compounds of organic origin which tend to promote the corrosion of iron. Such acids and compounds are mostly found in swamps, moors, and peat bogs, but, unfortunately, little is yet known of their action on iron and steel; in general, however, it may be regarded as detrimental by stimulating or favoring the passage of electric currents through the water. The same remark likewise applies to organic compounds derived from other sources, such as dead animals, manures, decaying garbage, etc.

Solutions of the alkalies and alkaline earths, like soda, potash, ammonia, lime, magnesia, baryta, and silica, do not cause iron to corrode directly, but the neutral salts of these bases seems to affect the metal unfavorably under some conditions. Attention to this matter has recently been called by the extensive external and internal corrosion of the steel pipes of the Coolgardie water works in Western Australia, which were completed only in 1903. A good account of this trouble is given in *Engineering Record* of May 21, 1910, and we learn therefrom that the pipe is buried for many miles in a soil containing considerable quantities of soluble salts, which give rise to corrosion when moisture is present; also that the water conveyed in the pipe is somewhat saline in character.

According to the published analyses, this water contains 25.5 parts per 100 000 of sodium chloride, 5.5 of magnesium chloride, 2.3 of calcium sulphate, 1.7 of calcium and magnesium carbonates, 0.8 of free and 1.2 of combined carbonic acid, together with small quantities of silica and iron oxide. It was found by experiment that it rusted steel much more vigorously than did London water, which contained 8.9 parts of combined carbonic acid. When the Coolgardie water was well aërated and allowed to flow slowly for

a week over a sample of the steel plate used in making the pipe, the loss of metal by corrosion was 2.38 milligrams per square centimeter of surface, while with the London water it was 1.72 milligrams. These figures correspond respectively to 0.004874 and 0.003522 pound per square foot.

It may also be remarked that the committee who investigated this case consisted of Sir William Ramsay, Mr. Geo. W. Deacon, and Mr. Otto Helmer. Their study of the subject led them to the conclusion that the essential cause of the corrosive action of all waters on steel and iron is the dissolved oxygen which they contain, and which excites an electrical action. By the removal of this oxygen, they found that this electrical action ceases, and the rate of corrosion is enormously reduced. As the most economical method of removing the dissolved air or oxygen, they recommend the spraying of the water into a vacuum chamber and then adding about 3 grains of lime per gallon. For preventing external corrosion, they advised scraping off the old asphaltic coating and applying a new one composed of bitumen and tar; then bedding the pipe on a cradle of lime concrete on the bottom of the trench, and covering the remainder of the pipe surface with a layer of slaked lime 0.5-inch thick.

Protective Coatings. The subject of protective coatings for thin iron and steel pipes is fully as complicated as that of corrosion. A great variety of different processes and materials have been tried and more or less enthusiastically advocated, but inasmuch as practice in this respect is far from being settled, it is fair to conclude that none of them has withstood successfully the crucial test of time. It is understood that this remark applies only to those processes which are not prohibitory by their expensiveness.

The protective methods are both metallurgical and mechanical in character. In the former the aim is to alloy the iron with one or more other metals, whereby the product will not corrode under certain definite exposures; while in the latter, only the surface of the metal is to be covered completely with some other element or complex substance that will not undergo chemical or physical alteration within the same range of exposure. Freedom from corrosion in the second method, therefore, depends wholly on preserving the integrity of the applied coating during the various

manipulations of the pipe, or in thoroughly repairing all incidental damage before the pipe is finally buried.

Various alloys of iron have been made which possess excellent rust-resisting properties, combined with fairly high tensile strength and good malleability, but, unfortunately, their cost is still too great to render them available in competition with cast-iron pipes. In the present state of metallurgical art, it is extremely difficult to devise a formula for such an alloy which will satisfy all the various requirements, as it is well known that small variations in the quantity of certain additions to pure iron affect greatly the physical properties of the alloy; hence it is very probable that a successful composition can be developed only by patient trial. In the writer's opinion, the most satisfactory results will be attained in this direction of experimental research.

Mechanical coatings with other metals, such as zinc, tin, copper, nickel, etc., are all too expensive on a large scale, and are easily damaged in the transportation and handling of the pipe in the field; neither has a practicable method of repairing such damage yet been devised. The same remark also applies to coatings with stable ferric oxide, or magnetic oxide of iron, as produced by the Bower-Barff process. Enamels made of various pulverized minerals and fused upon the surface of the iron or steel at high temperatures are generally too brittle and open to the objections of impracticability of repair in the field. This line of experimentation, however, is an attractive one, and the writer has learned that an economical process of this nature involving the use of pulverized clay and moderate temperatures is being carefully investigated by one of our leading contractors.

Next in order is the japanning process, which was first applied to one half of the Rochester conduit of 1894–5, and soon thereafter to a number of other steel pipe lines. There can be no doubt from all the experience thus gained that if the process is properly conducted an excellent protection to soft steel buried in the ground will be secured. Its cost, however, has militated strongly against its more general adoption, and the small thickness of the resulting film has been used as a potent argument in favor of thicker and cheaper bituminous coatings of alleged great durability.

Varnishes of different kinds of asphalt and coal-tar pitch, in

combination with a variety of other substances, have been used for many years, the usual method being to heat the mixture to about 320° Fahr. to render it liquid, and then to dip the pipe therein after having been thoroughly cleaned and heated to nearly the same temperature. In some instances the pipe has been dipped twice in this manner, with the expectation of remedying any accidental defects in the first coating and producing a thicker adherent film, but there is no good evidence that this procedure increases the durability of the pipe materially, as all such coatings are unavoidably injured while making the field joints.

The principal objection to these hot bituminous varnishes is the uncertainty of obtaining a mixture of uniform quality. This applies not only to the mixture itself in its heated state, during which a change takes place by the escape of volatile compounds, but also to the several constituents as delivered by manufacturers. In most cases the chemical composition of the materials varies greatly from time to time, due to changes of source of supply and mode of preparation. It therefore follows that each shipment should be examined by an expert chemist in order to maintain a proper standard of quality, and that all losses resulting from keeping the mixture at a high temperature shall be compensated in satisfactory manner. In practice very little is done in these directions owing to the expense of scientific investigation.

In regard to paints and varnishes that are applied at the prevailing temperature of the atmosphere, the writer ventures to offer but few remarks. From numerous experiments and observations during the past thirty-five years, with many different kinds of paint and varnish on small pieces of iron and steel buried for long periods of time in various soils, he has not succeeded in finding one that protected the metal satisfactorily from corrosion; but it should also be noted that not more than two thin coats had been put on the specimens. For repairing accidental abrasions of pipe coatings and defective spots found on exposing a pipe by excavation, he prefers to apply a hot bituminous material, such as the compound called "mineral rubber," or a hot mixture of coal-tar pitch with a small percentage of pure linseed oil. The reason for this preference is essentially because the coating hardens quickly, thus allowing the excavation to be refilled without much delay.

Stiffness of Thin Pipes. In designing a relatively thin metallic conduit, due attention must be given to the external forces acting upon it, as well as to the internal water pressures. Under usual conditions, the external forces are the pressure of the atmosphere, the weight of more or less of the backfill, and the support of the pipe at the bottom and sides of the trench. Of these, only the first is known with reasonable certainty, while the magnitude and direction of the others depend so much on variable circumstances that it becomes necessary to resort to assumptions.

If the backfill is either a soft and flowing mud, or a perfectly dry sand, a uniformly distributed external pressure acting in radial directions may be assumed; but as these materials are seldom available for the purpose, both the weight of that portion of the backfill which is carried directly by the pipe, and the manner in which the loaded pipe rests upon the bottom of the trench, will usually vary within wide limits. The result is generally a very appreciable deformation of the circular cross-section of the empty pipe, so as to make the section elliptical, the longer diameter being horizontal.

Not many observations of this kind have been published, and hence it is difficult to determine a reliable ratio of deformation for different diameters, thicknesses, and depth of backfill; but from the data collected by the writer relating to empty steel pipes from 3 to 6 feet in diameter and from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, it appears that when the depth of well-compacted earthen backfill over the top of the pipe is from 6 to 8 feet, the normal vertical diameter may be reduced as much as 10 per cent. These data are not sufficient to determine either the magnitude of the external load or its mode of distribution on the upper surface of the pipe, nor do they demonstrate that a greater deformation would not ensue if the backfilled material were heavier and looser, or contained more moisture, so as to reduce arch action and throw more weight upon the empty pipe.

In the cases mentioned, the bottoms of the trenches had been carefully graded, and the finest available material had been packed under the lower quarters of the pipe to afford a fairly uniform support. Obviously much depends on this feature, as otherwise the supporting reaction would tend to become concentrated at a

number of isolated points on the bottom, whereby the deformation would be increased. The same thing would also happen if large stones or bowlders were mixed with the earthen backfill over the pipe. Doubtless there are many places in every conduit where the load and support are at times far from being uniformly distributed, and when these forces exceed certain limits, the pipe will be in danger of collapsing if the internal water pressure is removed.

A recent discussion of this subject by Prof. A. N. Talbot will be found in Bulletin No. 22, University of Illinois Engineering Experiment Station, published April 29, 1908. Formulas for the largest bending moment and the corresponding stress in the outermost fibers of a thin elastic ring are there given for both concentrated and uniformly distributed vertical and horizontal loads; and by applying these formulas to the case of large steel pipes in which the metal has an elastic limit of 30 000 pounds per square inch, it will be found that when the depth of backfill is from 5 to 6 feet, and the weight thereof is assumed to be distributed vertically and uniformly over the surface of the pipe, the maximum fiber stress will approach closely to said elastic limit; and when the load is concentrated along the top and bottom lines of the pipe, the stress will generally exceed said limit.

It is, however, fair to consider that the earth which is in contact with the sides of the pipe will offer some resistance to displacement when the pipe begins to flatten, so that the aforesaid bending moment and fiber stress will doubtless be reduced somewhat; but as we have no trustworthy experimental data regarding the magnitude of such lateral resistances under various conditions of moisture in the material, it will be prudent to assume that depths of backfill of more than 6 or 8 feet are unsafe for thin pipes of the sizes and thicknesses mentioned above. In cases where this depth must necessarily be greater, provision should accordingly be made for giving the pipe an adequate stiffness, either by increasing the thickness of the plate, or by applying stiffening rings of angle-iron, or by bedding it more or less completely in concrete. The same procedure is also required where the pipe passes under railway tracks, or the shallow backfill is subjected to unusual loads.

The foregoing considerations indicate that an empty pipe of large diameter and small thickness is capable of withstanding only

moderate external loads of backfill without becoming seriously deformed; hence it is necessary to guard against the application of any additional loads, and especially against the formation of a vacuum in any part of such a conduit when the water is drawn off, as the external pressure thus developed may easily be much greater than that of many feet of earthen backfill. This action is to be feared most in highly porous and soft ground, but as all drained soil contains a large percentage of voids through which air can flow without great resistance, it should be assumed that atmospheric pressure against the exterior surface of the pipe is always in operation, and that it should constantly be balanced by an equal internal pressure.

Equilibrium in this respect exists naturally so long as both ends of the pipe are open to the atmosphere, either directly or by means of the water which fills the conduit. If, however, an orifice in some deep depression in the line is opened, through which more water will escape during a short period of time than the conduit can deliver with its available hydraulic grade, the pressure of the atmosphere at such orifice will be expended in the effort to maintain the continuity of the columns of water on each side of the orifice, thereby reducing the internal pressure at the adjacent higher elevations in the conduit. The same action occurs when a stop-valve in the conduit is closed and the water in the downstream section is permitted to escape.

To maintain the equilibrium mentioned in a collapsible pipe under all circumstances, it is therefore necessary to provide it with air-inlet valves at every main stop-gate, and also at every considerable summit. These inlet valves must have sufficient capacity to admit the required volume of air at nearly atmospheric pressure. To compensate for the resistance to free circulation of air in the ground, it may be assumed that the active pressure of the air against the exterior surface of the pipe is about four fifths of the barometric pressure, thus leaving a difference of 3 pounds per square inch available for forcing the air through the valve into the pipe whenever it may be required. In some cases the difference in pressure used to compute the dimensions of the air-inlet valves has been somewhat more than 3 pounds per square inch, but in view of all the uncertainties involved, it seems preferable to err on the safe side.

Details of Construction, etc. This paper has already greatly exceeded its contemplated limits, and hence further reference to details of construction must be omitted. It may be stated, however, that steel plates are now made into large pipes by three methods, viz., riveting, the use of lock bars, and welding. A fourth method of manufacture directly from the hot ingot, by the Mannesmann process of tube drawing, was also promised fifteen or more years ago, but for some reason it has hitherto been applied only to the fabrication of pipes not more than 12 inches in diameter. The welding process, on the other hand, has been developed in Germany to such extent as to admit of the production of seamless pipes 10 feet in diameter, and up to 150 feet in length. This operation, however, requires much more time and more costly apparatus than either of the first two methods, and hence it has not yet been adopted for large water conduits in the United States.

Riveted pipes are not patented, and do not involve great outlays for manufacturing plant, but they entail much expense for labor and have the disadvantage that their inner surface is roughened by many rivet heads and that a considerable portion of the metal at the seams is cut away by the rivet holes. The efficien y of a properly proportioned double-riveted seam is only about 70 per cent., whereas well-made lock-bar joints and welded seams exhibit in regular practice the same tensile strength as the adjacent plate metal. In regard to price per foot, the standard of comparison is obviously the cost of riveted pipe under proper competition. At present market prices of labor and materials, contractors bid about 4.0 cents per pound for soft steel pipe, including bituminous coating, moderate transportation, and jointing in the trench.

Under the same conditions, cast-iron pipe would cost about 1.3 cents per pound, plus the cost of placing and jointing. The diameter of the pipe and the water pressure now become important factors. Owing to its greater roughness of surface, it is found that the riveted pipe should have a diameter about 8 per cent. larger than that of the cast-iron pipe to give the same discharge on the given hydraulic grade. In the case of lock-bar and welded pipes, however, no appreciable increase of diameter is required. The internal water pressure determines largely the thickness of the metal, as it brings the tensile strength thereof into action. The

physical tests of soft steel and good cast iron show that these materials have ultimate tensile strengths of about 60 000 pounds and 16 500 pounds per square inch respectively, thus giving a ratio of 3.6 to 1.0, but general experience has established the practice of allowing the stress in the metal, due to the water pressure, to be only one fifth of the figures mentioned.

It has also been learned that the normal pressure in a pipe is considerably increased for short periods of time when the motion of the water is rapidly stopped by the closing of a main valve in the line. The magnitude of this increase is difficult to determine, as it depends greatly on the time taken to close the valve. From such observations on large conduits as have come to the writer's notice, this increase is about one half of the static pressure at the point under consideration; hence in computing the thickness of the pipe, at least 1.5 times the static pressure should be used in the formula. Furthermore, to compensate for unavoidable differences in thickness of shell and strength of metal, as well as to allow for a gradual reduction of thickness by corrosion, a certain arbitrary addition is usually made, which is about $\frac{1}{4}$ inch for cast-iron pipes and $\frac{1}{16}$ inch for steel pipes.

The formulas for the weights and costs of such pipes per linear foot are rather complicated, so that a comparison of results is not easily made. It must also be remembered that the costs will vary from time to time with the market prices of materials, labor, and transportation. Under the conditions stated above, however, and the further assumption that the static water pressure is 100 pounds per square inch, the writer has deduced two simple formulas for the approximate costs of large riveted-steel and cast-iron pipes, as follows:

1. For steel pipe, $y_1 = 0.4125.d^2$;

2. For cast-iron pipe, $y_2 = 19 + d(0.4845d - 0.851)$; in which y is the cost of the pipe in cents per linear foot exclusive of trenching, and d is the nominal diameter of the pipe in inches. The value of d to be used in these expressions is that of the cast-iron pipe, although the actual diameter of the steel pipe is 8 per cent. larger. It should also be noted that the expressions apply to diameters ranging from 2 to 6 feet and the aforesaid pressure.

These formulas indicate that the cost of steel pipe is less than

that of cast-iron pipe for all diameters, and that the difference in cost in cents per linear foot can be expressed by: $y_2 - y_1 = 19 + d(0.072d - 0.851)$. Applying this to the case of the Rochester conduit, where d was 36 inches, we have: $y_2 - y_1 = 81.7$ cents per foot, whereas the actual difference was in the vicinity of 50 cents, with rather light cast-iron pipe. With more conservative thicknesses for the latter and due allowance for overweight and loss by breakage it is probable that the difference would have been at least 60 cents per foot. The circumstances in this case, however, were of unusual character, as the lowest bidder declined to enter into contract, and the work was subsequently awarded to and performed by the next lowest bidder at a considerably larger cost to the city.

It will be noticed that the ratio $\frac{y_2 - y_1}{y_2}$ cannot be expressed in simple terms, and it is also evident that the life of a steel pipe is still invested with much uncertainty; hence it is not practicable to draw a general conclusion with respect to the economic advantage of such a conduit. If we assume the life of steel and cast-iron pipes at twenty-five and fifty years respectively, it will at once follow that a steel pipe will be equivalent economically to a cast-iron pipe, if the investment of the initial difference in cost at compound interest yields a sum at the end of twenty-five years sufficient to renew the steel pipe. When the cost of renewal is the same as the original cost, and the rate of compound interest is 4 per cent., financial equivalency will occur if the initial difference in cost is three eighths of the original cost of the steel pipe; and if the interest be 6 per cent., about one fourth of the original cost will suffice.

Conclusion. In the foregoing, attention has been called mainly to objections to thin steel pipes, and little reference was made to their many advantages. On this latter subject much can be said. As already indicated, the durability of such conduits is at present the principal matter of interest, and it is to be hoped that steel makers will soon direct their efforts to the production of a metal which will exhibit a much higher resistance to corrosion than has heretofore been attained. After this is accomplished, steel pipes will be used far more extensively in water works than heretofore.

DISCUSSION.

Mr. Francis H. Luce.* The speaker made it very plain that there is a great difference in the durability of wrought iron and sheet steel, but it seems to me that he has pointed out no very clear reason for that difference. I have had quite a large experience in making the comparison between wrought iron and sheet steel. For some twenty years I was engaged in the manufacture of enameled-ware kitchen utensils. Prior to 1892 we used wrought iron entirely. As the speaker stated, wrought iron is puddled and hammered and worked into a mass, while steel is practically molded, so naturally wrought iron is much more porous and of more open grain than sheet steel, which is very close and compact. Prior to 1892 we used nothing in this country for enameling for kitchen utensils, etc., but the old-fashioned charcoal wrought iron, and the enamel adhered so tenaciously to it, without the use of antimony or anything else to help it, that it was almost impossible to knock it off. I have pieces at home in my kitchen which have been in use almost constantly for many years. Ask your wives how long kitchen utensils of the present day will last, and they will tell you it depends entirely on the maid she has.

Up to 1892 there were two large manufacturers of kitchen utensils in this country, and the utensils were made under patents, and made, as I say, with charcoal iron. The patents ran out around about that time, and the manufacturers of tinware then began making enameled ware, and about that time the use of sheet steel became more general. The manufacturers of sheet steel claimed that they had perfected it to such a point that it would supersede wrought iron, and that it was just as good or better, and could be furnished for about half the price or less. Manufacturers started in using sheet steel for enameled ware, and reduced the price in proportion to the ratio of the cost of the base metal to the cost of the finished product. I think it figured somewhere around 20 or 25 per cent. The old line manufacturers found it impossible to meet the price without using sheet steel, and so they began to use it.

The people who started the use of sheet steel for this purpose

* Superintendent Woodhaven Water Supply Company, Woodhaven, N. Y.

loaded their enamel very heavily with antimony and arsenic and other substances to make it stick. The concern I was with tried to avoid that, and we experimented for a very long time and found finally that only by the interpolation of a coating of cobalt or nickel, we used nickel finally, applied a little differently from the ordinary electric coating, could we make the enamel adhere. We claimed that it adhered as well as it did on the old charcoal iron after interpolating that metal; but on applying the enamel in its raw state to the sheet steel without putting in anything between, in the same way that we applied it to the sheet iron, it would not hold at all, but would fall right off, at the least little touch or knock.

I believe that is the case with almost everything that is made that requires coating, owing to the difference in the porosity or grain between charcoal iron and steel. It used to be, if we wanted to put up leaders on our houses which would last for many years, we would put up galvanized iron ones and not tin ones. But now we put up galvanized *steel* leaders and they last only four or five years, whereas galvanized *iron* ones used to last thirty or forty. Why? Simply because the coating of zinc has not had an opportunity to go into the pores or the open grain of the base metal. Speaking from the experience I have had, I want to say that one reason that sheet steel pipes do not last anywhere near as long as the old wrought-iron pipe, is because of the lack of ability to make the coating stick. If there is no opportunity for the coating to take hold of the grain of the metal, so that you cannot coat it properly, naturally it will not last.

Mr. Edwin A. Fisher.* Some people have an idea that this new conduit, as we call it, which Mr. Kuichling has described, is rapidly going to pieces, and that it is almost time to reconstruct it, but as matter of fact the corrosion is confined to pittings, as Mr. Kuichling has stated, and the conduit, so far as its strength is concerned, is as good as ever.

We have spent on the conduit something like $8 000 to $10 000 a year. Mr. Little, the superintendent, has charge of that work. Whenever a leak is discovered, the pipe is in general uncovered each way from that point until we find no further evidence of corrosion.

* City Engineer, Rochester, N. Y.

The pipe is then scraped, as Mr. Kuichling has stated, and recoated. Last year several places were uncovered where the pipe had been recoated during the years 1902, 1903, and 1904, and no evidence of further corrosion was found in these recoated sections. Up to the present time about three miles of the conduit has been recoated out of a total of 26½ miles.

Mr. William Murdoch.* I think an explanation of the apparently enigmatical expression as to varnish on the conduit is that the conduit was coated with pure asphalt. I was quite interested in reading that it was coated with pure asphalt. The pipes, I think, were dipped and covered with asphalt. Now, I notice that the writer who is quoted here advises that the asphaltic coating be removed, for it seems to have been a failure, and that a mixture of bitumen and tar be used instead. That would mean asphalt and tar, which is just another name for asphalt. In other words, the varnish should have tar added to it instead of pure asphalt. That is my recollection of the description of the varnish which was placed on that pipe in Australia. I think that the explanation is that instead of pure asphalt the coating should be a mixture of asphalt and tar.

Mr. Leonard Metcalf.† I have been immensely interested in Mr. Kuichling's paper, which seems to me to be a very valuable contribution to our knowledge on this subject and a splendid summing up of information to date. Incidentally, as bearing upon Mr. Luce's comments, in explaining the difference in length of life by the difference in porosity of the material which makes it possible to get a coating which will adhere to the pipe, it may be interesting to call attention to what you all doubtless have observed, that in the case of nails, for instance, the old wrought-iron nails, which you have often seen in barns and old buildings, have stood up perfectly for twenty, thirty, forty, or fifty years. I have seen some older than that. There was no coating on them, and they were exposed to the rain, and yet apparently they did not rust. That is not true of the steel nails; they rust almost immediately. Take hinges, for instance, on some old structures, some of which have not been protected by paint.

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* City Engineer, St. John, N. B.

† Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

They too have stood up well when made of wrought iron. Consider some of the old wrought-iron hand railings which you have seen on some of our colonial houses many years old, which apparently had no coating upon them, and yet there were no signs of rust. That would have been impossible with steel hand railings, even though coated.

Mr. L. M. Hastings.* I have been interested in Mr. Kuichling's paper because in Cambridge we have had very much the same experience that they have had in Rochester. Our work there was done after the Rochester work had been completed, and we benefited a great deal by Mr. Kuichling's experience. We have four miles of 42-in. sheet-steel pipe, made very much on the same specifications that were used in Rochester. Of course the vital question is the durability of the steel, and that depends on the coating, and so a great deal of attention was paid to that at the time that the conduit was built in 1895. I looked at all available coatings, and it seemed to me then that the Sabin coating, which Mr. Kuichling and Professor Sabin had gotten up, was the best there was at that time.

Mr. Luce, comparing the old wrought iron and the sheet steel, has spoken of the comparative porosity of the two. That question came up in considering the matter of the application of the Sabin coating, and the matter was provided for by heating the metal. In applying the Sabin coating one essential point is that the pipe itself should be heated very hot, so that the pores of the steel will be open, and then dipped immediately in the hot mixture.

As to the actual resulting durability in Cambridge, I cannot give any very definite information, because we have not uncovered the pipe lately. But in several places I have seen portions which have been exposed, and the pipe itself, where it has not been interfered with by outside influences, or by electrolysis, has proved very durable. Even where the body of the Sabin coating has been knocked off by picks, there seems to be a thin film of coating adhering to the steel which has prevented rusting. It was very interesting to me to note that the most of the flaking occurred at the lower end of the pipe, where the varnish was probably two or three times as thick as at the top of the pipe as it was dipped in

* City Engineer, Cambridge, Mass.

coating. But even there, where the coating had flaked off, we actually found in the ground that the thin skin or film, or underskin, as you might call it, had penetrated the metal and had preserved it from corrosion

I might say in regard to the durability of steel and cast iron, and wrought iron, that at the time of the construction of the pipe, out of curiosity, and as matter of experiment, I had a number of plates of coated steel, coated iron, coated cast iron, and three sheets of uncoated metal put into the water and kept there for a year or two, just to see what the effect would be. They were very carefully weighed before they were placed in the water in Fresh Pond, our own water supply, and after fifteen months, I think it was, I pulled them out and weighed them up again. I haven't the figures with me, — they will be found in the American Society of Civil Engineers' reports,* — but I know that the general result was that there was not much difference between iron and steel in the action of the water on the plates, for the time during which the experiments were made.

I think our coating has proved very satisfactory. Of course it will not protect the pipe from electrolysis. We found that our pipes in two or three places were affected by the action of electricity, but of course that is something which no pipe will stand. We have suffered very severely from that in Cambridge, both on the cast-iron and steel pipe, but so far as the action of the soil is concerned, I believe we have had little or no difficulty from the acids in the soil. When we have had occasion to tap on to our main steel pipe line, the inside, as I remember, has shown very little deterioration; the water has not acted seriously on it.

Mr. W. C. Hawley.† I am glad Mr. Kuichling has called attention to the external forces which act upon large pipes. That is a matter which is often overlooked, and we still find in specifications occasionally that the pipes shall rest upon two or more blocks. I don't know why we should wish to concentrate the load, but it is sometimes done, and I have had very unpleasant experiences, in the last few years, with 36-in. and 42-in. pipes which have burst under such conditions.

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* Transactions American Society Civil Engineers, Vol. XXXVI, p. 504.

† Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

Mr. Kuichling has confined his paper to a consideration of pipes laid in ordinary soil, not in contact with salt water. It may be interesting to some members of the Association, who have salt water to contend with along the coast, to refer to the Atlantic City 30-in. steel pipe line, which was laid nine years ago. Mr. Kuichling was the consulting engineer, and we recommended to the board of water commissioners, and they concurred in our recommendation to city council, a wooden stave pipe as being preferable to either cast iron or steel. The council, however, preferred steel pipe, and it was laid. We prepared the specifications very carefully. The pipe was dipped in mineral rubber and then, in order to protect it during transportation, it was immediately stood up in a stall and covered with burlap, brushed into the hot mineral rubber just as paper is put on a wall. We expected that the burlap would rot in a few months, but it did not. However, it protected the pipe during transportation.

The pipe was delivered in February and March. The first half mile was carted out on to the salt meadow, which, fortunately, was frozen over for the first time in a great many years. The next half mile was unloaded directly from the cars on to the meadow, the weather having moderated in the meantime, and rolled from there to the pipe line. The pipe line was approaching the railroad at an angle of about 15 degrees, and I think the maximum distance of rolling the pipe was perhaps 600 or 800 ft. After the pipe was finished there was no trouble for about three years, if I remember correctly, and then in that half mile where the pipe had been rolled across the meadow a number of leaks were found, and within two years more I think something like 60 leaks were found in that section. But very few leaks were found in other parts of the four miles of pipe up to that time. Since then the leaks have gradually become general over the whole main, and I may state that to-day the pipe line has very nearly reached its limit of service. A great many holes have been filled by driving in wooden plugs, and part of the line has been encased in concrete. It seems to me that this shows that where the coating was damaged, probably by the stalks of meadow vegetation in the half mile where the pipe was rolled to the ditch, the metal was at once attacked. In the balance of the pipe it has taken longer, and it may be either

the fault of the coating or it may be some inherent trouble with the metal. It is a source of some satisfaction, however, that at the present time they are laying a 48-in. wooden stave pipe across the meadow at Atlantic City.

MR. ALLEN HAZEN.* My first experience with steel pipe was in 1897, when 8 000 ft. of 48-in. steel pipe were laid to connect the filter plant then being built with the pumping station of the Albany water works. Mr. Kuichling was consulted because he was believed to be one of the best posted men in the United States upon pipe questions. This pipe is still in service, and as far as I know has never been heard from.

The primary reason for using steel pipe is, of course, one of cost. At Springfield, Mass., for instance, a line of 42-in. pipe 12 miles long, completed a year ago on competitive bids for cast-iron and steel pipe, cost only two thirds of the low bid for cast-iron pipe. In other words, the steel pipe cost $2 where the cast-iron pipe would have cost $3. For large pipe lines that proportion perhaps indicates roughly the comparative costs that have held in the last five years.

The steel pipe at Springfield is very much stronger, more reliable, and tighter than any cast-iron pipe could be made. On the other hand, it is perhaps less durable. Of this we do not know much. Some steel pipe lines fifteen to twenty years old are still in service, in excellent order, with no apparent reason why they should not last for twenty years longer, and perhaps for an indefinite period thereafter.

More than 99 per cent. of all the material that goes into steel pipe remains without injurious or rapid corrosion. Where injurious corrosion has been found, it is a strictly local phenomenon. It occurs where there have been defects in the steel plates or in the coating. The injurious corrosion has been confined to these places, or, in other words, to a few pits, covering, as Mr. Kuichling has shown, hardly more than an infinitesimal portion of the whole surface of the plates. As the plates have been able to resist corrosion in ninety-nine and a large fraction per cent. of their whole surface, it would certainly seem that they might be perfected so as to resist corrosion in all parts.

* Civil Engineer, New York.

The trouble at the present time is that we do not know enough about the factors that cause the starting of this injurious corrosion. We want to know more about these causes, and we are going to find out about them, and we must all work together along this line.

The wrought-iron pipe used in lines laid twenty years ago and more seems clearly to have been more durable than the steel pipe that succeeded it and is used to-day. Wrought iron can still be secured at an increased price, but at a price that would not in itself prevent its use in large pipe lines. A practical objection is the limited size of plates that can be rolled from it. The largest wrought-iron plates that have been successfully rolled are much smaller than most of the plates used in steel pipe lines at the present time.

Mr. Knudsen has mentioned a new product, called "ingot iron," which is almost chemically pure iron, and which promises a great deal to the pipe business, if it can be made cheaply and rolled in sufficiently large plates.

The general system of steel pipe and wrought-iron pipe represents a more scientific, efficient and economical use of metal than is required in cast-iron pipe. With the improvements that are being made it seems practically certain that it is going to replace cast-iron pipe for everything above 36 in. in diameter. For 36-in. pipe and smaller, of course, there is a field that is now held and probably will be held for a long time by cast-iron pipe.

Mr. Morris Knowles.* Pittsburg has laid a number of steel pipe lines, and I will refer to a few of them briefly.

The Allegheny Main, so called, running from Montrose Pumping Station to the reservoir on the North Side (formerly the city of Allegheny) was laid in 1896–7. It is 36 in. in diameter and made of steel plates, protected with the hot applied and baked coating of A. H. Sabin. This main runs directly through the filtration works and was uncovered in five places during the building of other structures in 1905–6. The line was found to be generally in good condition, as far as the exterior was concerned. We, of course, did not see the interior. The coating was in fair condition and apparently there were no pits.

* Chief Engineer, Bureau of Filtration, Pittsburg, Pa.

Since that time, however, serious defects have been located a little below the filtration works in the borough of Sharpsburg, where the line had evidently been subject to some great corrosive action, either electrolysis or soil conditions. The soil at this place was partly clay and partly slag and ashes, while that at the filtration works was sand and silt from river deposit. There were a number of places within a local area in Sharpsburg where the plate had holes completely eaten through. These were tapped out and ferrules inserted in the usual manner. Since that time screw plugs have been used elsewhere for the same purpose, placed in a similar way.

There are two rising mains from Brilliant Pumping Station to Highland Reservoir No. 1. The first one, of wrought iron, was laid in 1879 and coated with cold asphaltum paint. The second line is a 50-in. steel, laid in 1891, and coated with mineral rubber dip. The first line was entered some four years ago, and while the rivet heads were somewhat deeply scored, with considerable incrustation and heavy pitting, the line would not be considered to be in serious condition for its age.

A short time ago there was a break in a cast-iron line on the hillside, in the vicinity of these rising mains. For a short distance there was a large trench open for laying a new steel main. The rush of water gushed out of the broken line, undermining and exposing the others. The settlement under the steel main was sufficient to cause it to be ruptured in two places and we were thus able to make an inspection of the interior of this line at that time. There was much scoring of the rivet heads; also, tubercles the size of a walnut, with pits underneath. Later, upon exposure to the atmosphere and elements, these tubercles dissolved and the rust seemed to extend and travel underneath the coating between the pits. Upon original inspection, while the pipe was wet inside, the coating seemed to be in good condition, as well as the steel plate underneath, and apparently would have remained so if it had not been for the drying out, due to exposure.

Some experiments, made in 1901, determined the value of "n" in the Kutter formula for 3.8 feet velocity as .022 for the twenty-one-year-old, painted wrought-iron pipe; and .017 to .019 for the eleven-year-old hot-dipped steel pipe which had been cleaned once.

The exteriors did not lend themselves so well to comparison, because about the wrought-iron line there was a protecting layer of sawdust and crude oil, about 2 in. thick, and the line was very thoroughly cared for by this method. The steel line was not in as good condition, and had a number of places abraded; the exposed areas have since been recoated. Some of the deterioration of coating on the outside may have been due to the scour of the sand and water.

It is interesting to note that at the places where the steel main broke, due to the weight of the undermined section, there was not a single place where the plate had been torn, and in every place rivets were sheared. It is interesting to see how the rivets, which were of wrought iron, first started to tear at the heads and were then cut off completely at the face of the plate.

There was a 50-in. steel line about 5 miles long, laid in Pittsburg in 1905–6, which was also coated with mineral rubber dip, through the city's streets, but which is of too recent history to afford much comparison. Except for a small portion of the end of this line, about 30 in. in diameter, no opportunity has been had to see the interior, but in this place it was in excellent condition. Wherever exposed it has been found to be in good condition, except at one spot on the South Side, on the 30-in. line above mentioned, where electrolysis had done considerable damage before it was found out.

Pittsburg has suffered from electrolysis, as most other cities having a traction system have. The remedy has been to bond lines by copper cables running from proper points back to the bus bars at the power station, and this has been quite successful. The steel line offers a ready means for transportation of the electric current, when it is once in the metal, because there are no lead joints, except at some valves, and these have copper bonds around these joints. The method used is apparently paying for itself and is very successful, not only in steel line, but for the cast iron, where there is no bonding around the joints.

Mr. R. S. Weston.* I had hoped that some of the engineers from Pittsburg would describe the process of making the iron or steel used in the manufacture of riveted pipe, for I think the

* Sanitary Expert, Boston, Mass.

members would have been as much interested as I was when a prominent metallurgist took me through a large steel works the other day. The process of making open-hearth steel consists in heating the pig iron, which contains much carbon, silicon, phosphorus, and sulphur, in the presence of oxygen in such a way that the impurities are burned out by the oxygen or absorbed by the basic or acid clay lining of the furnace. To furnish additional oxygen and to increase the fluidity of the molten metal, iron oxide, ferro-manganese, and other materials are added in the form of lumps which are thrown into the furnace by hand. The furnaces for making open-hearth steel consist practically of a shallow tank with a refractory lining. Over this shallow tank or hearth a gas flame plays while the metal melts into a seething mass. The sulphur and carbon are burned out and the phosphorus becomes burned out or absorbed by the lining. At the end of the process which, as Mr. Kuichling has said, is determined largely by the experience of the iron master, the molten metal is run into large ingot molds. These may be as large as 20 in. square and 6 or 8 ft. high. These ingots cool or freeze exactly as do blocks of artificial ice. The pure steel cools first and is on the outside of the ingot, while the center, especially near the top and bottom, contains the highest percentage of impurities. When the ingot is rolled or hammered the impurities exist as streaks in the finished product. These streaks of impurities may consist of manganese sulphide, a compound of manganese and sulphur. This fact is not surprising when it is remembered that the manganese in the form of lumps of ferro-manganese as large as one's fist is thrown into the furnace by the shovelful and its mixing with the molten metal is dependent very largely upon the chemical reactions within the furnace and that agitation which occurs when the metal is run into the ladle and from thence into the molds. There is always the danger that the product will not be homogeneous. When the ingot which has its impurities more or less localized is rolled out into a sheet, the latter will also contain localized impurities. The impurities have a different electrical potential from the pure steel; electrolysis is set up in the presence of water, and wherever conditions exist in any part of the metal where electrolysis takes place, that part will corrode a great deal more quickly than where the metal is

homogeneous. Thus pitting occurs in spots adjacent to small particles of impurities. Wrought iron is much less readily attacked because it is usually more homogeneous. There is no reason, however, why steel cannot be made as homogeneous as wrought iron if sufficient pains be taken with it.

The *Engineering News* * about a year ago published a very interesting article by Prof. Henry Fay, of Boston, on the failure of steel rails due to the presence of manganese sulphide. It was found that the manganese sulphide would segregate in spots in the rail and would form a center for corrosion or deterioration. It was often the case that the rail would crack, and at the point of fracture manganese sulphide was found in almost every case. Other investigators have shown that steel cannon have failed for the same reason. This experience has led to the production of ingot iron, as several speakers have mentioned. This latter contains little manganese, and more care is taken to have the metal homogeneous. The manufacture of steel plate from this ingot iron seems to offer the greatest hopes for the production of a metal highly resistant to corrosion.

Regarding coatings, the speaker would say that it has always seemed to him that the first requisite of a coating is to keep the water away from the pipe, and the reason why some of the varnish coatings like the Sabin coating succeed better than some others is because it is baked on the surface of the hot metal. This process tends to drive the water away from the metal and to allow the coating, so to speak, to get next to it. Mr. Kuichling's remarks that the definition of asphalt is in a muddy condition is explainable to some degree by the fact that it is the "mud" in the asphalt which makes it hard to define. Trinidad asphalt may contain 25 per cent. of matter besides what chemists call, in a very indefinite way, bitumen. This 25 per cent. of material is more or less soluble in water, consequently if one puts Trinidad asphalt or any partially soluble asphalt upon a pipe or upon iron or steel, the soluble matter will dissolve out, leaving a porous coating, the water will come in contact with the iron, and because iron is soluble in water, and especially so in water which contains neutral salts or acid salts, the metal will corrode, the more readily

* *Engineering News*, Vol. LXIII, p. 381.

the more streaky is its structure. On the other hand, if certain mineral waxes and coal-tar pitch preparations were used, better results would be obtained. Pure bitumen is practically insoluble. It has been found between bricks exposed by the excavations at Nineveh. It is difficult to apply any coating to a metal in a continuous sheet and to get it on to the iron without a layer of moisture beneath; thus many coatings fail because of imperfect application.

Mr. Morris Knowles (*by letter*). The steel and wrought-iron mains referred to have taper joints, with smallest diameter 50 in.; thickness of plate for steel main, $\frac{3}{4}$ in. for 1 800 ft. and $\frac{5}{8}$ in. for 2 000 ft. There were no records of the thickness of the wrought-iron pipe, and present calipering would be subject to too much error.

The steel main was cleaned in 1896 by scrapers and wire brushes and then repainted.

Mr. E. Kuichling (*by letter*). The discussion of the paper has brought out a number of highly interesting experiences and opinions. Mr. Luce's notion that wrought iron is more porous than mild steel, and that preservative coatings of paint, varnish, or enamel adhere more tightly to surfaces of wrought iron than to steel, because some of the coating material flows into open pores, implies that the pores are of such shape as to lock the covering substance mechanically to the metal by a vast number of extremely minute bulbous stems or dovetails. A porous structure of this kind was not revealed by the microscope in many examinations of iron by the author, except after the action of strong acid, and then only in comparatively few places. It is possible, however, that the manner of preparing and viewing the samples was at fault.

The statement is also often heard that the surface of rolled wrought-iron plate is much rougher than that of steel plate. This may be due to differences in the finish of the rolls, as there seems to be no good reason for the same rolls producing a rough or porous surface on one metal and a smooth or dense surface on the other. The chances for variation in the composition of the coating material, and its mode of application, are far greater than any possible difference in character of surface. Roughness of metal surface implies that the coating is uneven in thickness, and hence

of unequal strength and intensity of adhesion, whereas the opposite results are claimed. The subject requires much closer study before a satisfactory explanation can be given.

In considering the life of relatively thin pipes of iron and steel, the original thickness of the metal seems to be a very important factor. The steel plate of the 60-in. Allegheny main, cited by Mr. Knowles, is 0.5 in. thick, and the thickness of the two Pittsburg rising mains are said to be considerably greater. It is needless to say that under like conditions of corrosion a thick plate will last longer than a thin one.

The computed values of the Kutter coefficient "*n*" given by Mr. Knowles for the Pittsburg riveted mains are very interesting, but they should be supplemented by stating pipe diameters and plate thicknesses, as well as time and manner of cleaning the steel main. In a description of the Pittsburg water works published a number of years ago, it was stated that the old wrought-iron pipe was 48 in. in diameter and 0.75 in. thick. This plate thickness seems excessive, but if correct it will account for the high value of "*n*," owing to the relatively large difference in diameter at the circular joints.

The remarks of Mr. Weston furnish excellent reasons for the pittings so often found in steel pipes, and also for the occasional failures of bituminous coatings. They indicate that there is room for improvement, not only in the fabrication of steel, but also in the composition and application of preservative coatings, and it is to be hoped that he will point out in other papers how advances in these directions can be attained.

THE CORROSIVE ACTION OF WATER ON METALS.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON.

[*Read September 23, 1910.*]

It is not intended that this paper be a theoretical treatise on the nature of water and its solvent action on metals, for that side of the question has been discussed ably by Whitney (1),* Cushman (2), Walker (3), Kanolt (4), and others, and in the JOURNAL of the New England Water Works Association by Mr. Harry W. Clark (5), who has described the investigations which he made, under the direction of the Massachusetts State Board of Health, into the action of water on lead service pipes; also by Mr. Freeland Howe, Jr. (6), whose paper treats of the general subject. Furthermore, it is not the plan to list all the troubles which are familiar to most water-works managers, but rather to outline a few of the causes, effects, and remedies, with the hope that those who meet with the same in practice may be moved to contribute from their experience to the discussion.

WHY DOES WATER CORRODE OR DISSOLVE METALS?

There is no metal which is absolutely insoluble even in pure water. There is little pure water obtainable, and the greater the amounts of certain impurities in the water, the greater the solvent action it has for metals. Iron is quite soluble, zinc more so. This tendency of a metal to go into solution is called the "solution pressure"; that is, the molecules of the metal tend to diffuse among the molecules of the water just as a little sugar, even if not stirred, tends to diffuse in a cup of hot water and to sweeten the whole cupful. The amount of any metal which will dissolve in absolutely pure water is very limited, and the action soon comes to a standstill. The theory of this action has been explained by physical chemists and is known to most of you as the "*electrolytic theory of corrosion.*" This theory states that water is partly dissociated into its hydrogen (H) ion and its hydroxyl (OH) ion.

* Numbers refer to the references at the end of the paper.

"*Ion*" is a synonym for "*component*." When a metal is immersed in water a "*battery*" or electrolytic effect is produced, and a certain amount of the metal is replaced by the hydrogen component of the water. The hydrogen goes into gaseous form and the metal into solution. In pure water this action soon comes to a standstill, because a film of hydrogen gas collects on the surface of the metal and, being a non-conductor, really shuts off the current, that is, polarizes the iron. Whenever anything like an acid — which increases the hydrogen side of the equation — or oxygen — which "*depolarizes*" the iron — is present, the action is accelerated; and when any substance containing hydroxyl, like lime or caustic soda, is present, the action is hindered or retarded. For example, iron dipped in weak acid dissolves rapidly, while the same dipped in lime water remains bright indefinitely. The most common acid in water, and the one most important, is carbonic acid (H_2CO_3), which dissociates into H and HCO_3. Thus, when large quantities of carbonic acid are present, the number of hydrogen (H) ions is greatly increased, and the well-known corrosive action of such waters is evidenced.

When oxygen is dissolved in water an oxidizable metal like iron corrodes more rapidly because the oxygen depolarizes the iron upon which the hydrogen tends to precipitate. It also rusts and throws the metal out of solution as fast as it dissolves; insoluble iron precipitates and leaves room for still more of the metal to go into solution. This oxidizes in turn and precipitates, and as fast as the iron oxidizes, the hydrogen, because of the so-called depolarizing action, is pushed off the surface of the metal in the form of bubbles, thus preventing the formation of a film of gas thick enough to protect the metal against solution. Waters frequently contain more than 14 parts of oxygen per million. The amount dissolved is dependent upon the temperature and pressure. Deep well waters are naturally quite free from oxygen, while surface waters are nearly always saturated, and those which contain very active growths of algæ are frequently supersaturated. On the other hand, ground waters, especially those from shallow wells, frequently contain considerable oxygen, probably because they are supplied in part by surface water. Therefore one may expect to find iron rust in most waters which attack iron. Some deep well tubes,

however, are corroded and waste away without the slightest trace of rust.

The kind of metal present also affects the degree of action of the water. All metals vary in their degree of solubility. Sodium, potassium, and calcium dissolve very rapidly and with the evolution of considerable heat; while gold and platinum are practically insoluble even when certain strong acids are present. Between these extremes lie the different metals used in water-works practice. The following table of metals, arranged in the order of their solubilities, is of interest.

Aluminum.
Zinc.
Iron.
Nickel.
Lead.
Tin.
Copper.

The order given in this table has been determined by measuring what is called the "*solution pressures*" of the various metals. These results give them their relative positions in what is known as "*the potential series of the metals.*" The fact that water acted on metals in the order given in the table was known by practical men long before it was confirmed by the experiments establishing the theory.

Electrolysis is another factor which influences corrosion. If iron and zinc are placed side by side in water which attacks them but slightly, and connected with one another, the zinc will go into solution and the iron remain. This principle is made use of in copper mines where the waste waters, containing valuable copper, are passed over iron chips, when the iron goes into solution and the copper takes its place. In similar cases the least soluble metal will remain unaffected.

It is a well-known fact that no iron dissolves from galvanized iron pipe until the zinc near the point of corrosion has disappeared. Lead-lined and tin-lined iron pipe frequently fail because the iron has an increased tendency to go into solution in the presence of lead or tin. Tin-lined iron pipe is more subject to corrosion. It is a fact that tin shrinks after it crystallizes, leaving numerous

cracks through which the water can pass to the iron pipe through the tin lining. It has generally been believed that a tin lining will protect lead pipe against solution, but experiments, with the assistance of Miss H. R. Hosmer, with lead pipe lined with pure tin and exposed to the action of distilled water, natural surface water, and natural ground water, showed the presence of varying amounts of lead in all of the sixteen samples held in contact with the tin lining, and — what was surprising — the absence of tin from every one. The amounts of lead dissolved from tin-lined pipe in the above-mentioned experiments are given beyond. In these experiments the sample of ground water and one of the three samples of surface water were kept in the laboratory for several weeks. They lost carbonic acid while standing, and their diminished corrosive action due to this loss may be noted in the following table of results, experiments numbered 1 to 14.

Solubility of Lead from Tin-Lined Lead Pipe.

Experiment Number.	Kind of Water.	Period of Contact.	Parts per Million.	
			Lead.	Tin.
1	Ground.	1 day.	4.60	0.0
2	Filtered surface.	1 ,,	10.10	0.0
3	Ground.	5 days.	1.10	0.0
4	Filtered surface.	5 ,,	5.10	0.0
5	Ground.	18 ,,	2.80	0.0
6	Filtered surface.	18 ,,	4.00	0.0
7	Ground.	14 ,,	3.80	0.0
8	Filtered surface.	14 ,,	3.80	0.0
9	Ground.	19 ,,	2.20	0.0
10	Filtered surface.	19 ,,	2.20	0.0
11	Ground.	43 ,,	0.70	0.0
12	Filtered surface.	43 ,,	1.00	0.0
13	Ground.	21 ,,	1.50	0.0
14	Filtered surface.	21 ,,	4.00	0.0
15	Unfiltered surface.	15 ,,	2.20	0.0
16	Unfiltered surface.	15 ,,	3.50	0.0

No tin was dissolved in the presence of lead. The two metals have a different solution pressure and the lead will dissolve as long as any tin is present. This was confirmed by another experiment where pieces of pure tin and pure lead were connected with a wire and suspended in water.

The stray electric currents from street railways, lighting and telephone systems, when pipes are laid in damp soil or are exposed to water, will carry metals with them just as metals are carried from one pole to another in an electric plating bath. The action is exactly analogous to the action described above, where the two metals connected with one another were immersed in water. Solution generates electric current, and electric current can cause solution. It may be said that the essential factors for the solution of any metal in water are an electric current and the presence of a less soluble substance of a different electrical potential. For example, if a piece of iron in water be connected with a piece of scale which has a different potential, an electrical current will result and the iron will be dissolved rapidly. As is well known, wrought-iron services are very long-, and steel services very short-lived. The former are made of nearly pure iron; the latter contain more scale, more particles of manganese sulphide, more sand grains and other impurities tending to establish electrical currents when the metal is exposed to water, thereby increasing the speed of solution or corrosion. The fact that the wrought-iron grillwork on old buildings lasts so much longer when exposed to the elements than the modern steelwork is an evidence of this fact.

Whipple (7) (Eng. Rec., *62*, 118) investigated the cause of the "red water plague" at Springfield, Mass., and found that it was not due appreciably to the introduction of a new filtered water supply, as had been feared, but rather to the use of unprotected steel tanks and of low-grade galvanized steel pipes for the hot-water supply systems where most of the trouble occurred. This action was far more apparent than any action due to the removal by the filter of organic matter, which in many water supply systems forms a protective coating on the insides of pipes and tanks and aids in the resistence of corrosion, but which when removed exposes the pipes to the action of the water.

The waters most apt to cause electrolysis are those which contain large amounts of dissolved mineral salts, such as chlorides, carbonates, and sulphates. These increase the conductivity of the water, and hence the corrosion due to electric currents. Mr. W. F. Monfort (8) has shown that the corrosion of pipes, meters, and

valves of the St. Louis supply, after treatment with lime and ferrous sulphates, was due chiefly to this electrolysis. His investigations showed that the zinc coatings on galvinized iron pipes and gratings disappeared rapidly, and that in meters where bronzes of three different compositions were used, those containing the highest proportion of the more readily soluble zinc and aluminum corroded most rapidly. These facts were especially interesting because the water did not attack iron, although it was alkaline and contained neutral carbonates and at times free lime (therefore, hydroxyl). There is no *red water plague* in St. Louis, although the water does attack appreciably the somewhat soluble aluminum. Naturally, Mr. Monfort recommends that homogeneous materials be placed in contact with this water and that one kind of bronze be used for meters and valves. Tinning bronze did not protect against corrosion any more than it protects lead or iron pipes.

Another source of acid and corrosion in water is the humus matters in peaty waters. The water of Dismal Swamp of Virginia, for example, attacks iron rapidly. But, as Mr. George W. Fuller (9) states in a recent paper, "It does not seem to be perfectly plain, however, how far the acid character of peaty waters may be due to carbonic acid and how far to complex and obscure organic compounds"; yet such waters, especially the moorland water in parts of England, have so marked an action on lead pipe as to make it necessary to treat them with lime or soda in order to neutralize the effect.

Mr. J. W. Ledoux (10) has shown that the swampy water which supplies Charleston is highly corrosive before filtration. With the removal of most of the organic matter by treatment with sulphate of alumina and filtration, the corrosive effect is reduced to a minimum. The treatment, however, cannot be carried to such a point that all of the color is removed. To do this it is necessary to add so much sulphate of alumina that there is an excess, and corrosion due to this excess is produced. Corrosion due to this cause can be corrected by the addition of lime; but if this be done the removal of color is not satisfactory. Mr. Ledoux does not state whether or not he has tried the effect of adding lime after the color has been removed by filtration with the aid of a sufficient amount of sulphate of alumina. Experiments in England by C. C.

Smith (11) would indicate that such a practice would be successful.

The waters most liable to attack metals are pure waters containing large amounts of carbonic acid and oxygen. Waters which contain, like the St. Louis water, high amounts of dissolved neutral salts are most liable to set up electrolytic action when two different metals are exposed to them.

PROTECTIVE COATINGS.

The action of the water is retarded by coatings which form on the insides of metal pipes, the simplest and most common of which is iron rust. This forms frequently a so-called tubercle, beneath which the iron is often bright and rust-free. In this case there is sometimes an accumulation of gas — perhaps hydrogen — which prevents the further action of the water. When ground waters act on lead pipe, a basic carbonate of lead collects on the inside. This retards the action, just as does the iron rust, and it is a matter of common knowledge that such waters attack new lead more rapidly than old, that is, those on which the coating has formed. Again, the suspended silt in some western river waters acts in a similar manner. There are in existence iron water-works intakes in these streams which have been in use for over fifty years and which show no appreciable corrosion.

The organic matter in many New England surface waters effectually protects against corrosion. The writer has had the lead service pipes of Concord, Mass., under observation for ten years, and observed no more corrosion in the year 1910 than in the year 1900. Frequently this organic matter is removed by filtration, and after a few years complaints begin to appear, due not so much to the slight percentage of increase in the amounts of carbonic acid or conductivity (due to the addition of sulphate of alumina) as to the disappearance of the gelatinous organic coatings from the insides of the pipes. At Exeter, N. H., which has been supplied for four years with filtered water, always alkaline and free from sulphate of alumina, there have been some complaints recently because of "*red water*" in the hot-water systems. This may be due in part, as at Springfield, to the poor quality of the pipes and tanks, but the writer believes in great part to the removal of the

organic matter by filtration. The effect of filtering such water is like changing from a colored surface to a clear ground-water supply. This change has been known to increase corrosion. Slow sand filters might effect an equal or greater increase in the amount of carbonic acid, but because the removal of organic matter would not be so complete, it is probable that there would be more protection afforded by the organic matter collecting on the insides of the pipes. In the writer's opinion most of the increased corrosion of pipes ascribed to filtered water is due to the withdrawal of organic matter which would form a protective coating.

Monfort (8) has shown that calcium and magnesium carbonates collect on the insides of the service pipes at St. Louis and protect them against corrosion. Similar observations have been made where water softened with lime and soda has been distributed.

The lining of iron pipes with tin is some protection, but unless the fine cracks become filled, the iron will corrode. Lead is not so apt to dissolve from lead-lined iron pipe as from pipe made of pure lead; the presence of iron helps to prevent this action, the iron being the more soluble metal.

Certain silicates in water form protective coatings, and the best artificial lining for service pipe is the silicate of calcium which one one calls " hydraulic cement." Pipes lined with cement have been in use for many years, and recently one city has been advised to line a riveted steel pipe with this material. While cement lining has the disadvantage of being brittle, it is an effective protection against corrosion, both because of its alkalinity and its impervious nature. It should be recommended for services where water attacks lead or iron pipes and where wooden pipes are impracticable. The idea would be an elastic alkaline coating, say a bituminous Portland cement.

HOW CAN CORROSION BE AVOIDED?

While the causes of corrosion, though far better understood now than formerly, may be obscure, the remedies are obvious and not difficult. An excess of carbonic acid in water may be removed by aëration or by the addition of sufficient lime to combine with it. Aëration generally suffices. As an increase in the hydrogen ions increases the corrosive power, so an increase in the opposite hydroxyl

ions decreases it. The addition of enough alkali — that is, hydroxyl ions — to make a water neutral to phenolphtalein (an aniline dye used to test for alkali) is generally sufficient to overçome this corrosive action. While this practice is not usual in this country, it is common enough in England to warrant its adoption wherever necessary. If a water contain dissolved salts, even though alkaline, homogeneous metals should be used in contact with it. The insides of meters, valves, and pipes, wherever possible, should be of such a composition that electric currents will not be generated. Cheap steel pipe containing scale and other impurities should be replaced with high-grade metal, and where necessary, wood and cement-lined pipes should be used. No one should attempt to fasten a copper screen with galvanized iron staples unless it is desired to have the staples disappear. If, on the other hand, a galvanized iron screen be fastened with copper staples, the screen will go first.

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DISCUSSION.

Harold C. Stevens, Esq.* The Board of Water Supply of the city of New York, in connection with the design of sanitary works for the protection of watersheds through which the Catskill aqueduct is being constructed, has had occasion to seek information regarding the effect of hypochlorite of lime solution upon metals, and in the operation of the works has gained further information. Systematic observations have not been made, and the corrosive effects under apparently similar conditions have differed quite widely; but the data obtained indicate in a general way what to expect.

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Wrought-iron pipe is most readily affected. The inverts of 2-inch pipes having a trickling flow of a one per cent. solution through them have been completely rusted through in about four months. Three-inch galvanized iron pipes, conveying at different times one per cent. and one-half per cent. solutions and flowing full, were replaced after about a year's service, not on account of rusting through, but on account of clogging due to the formation of tubercles and the accumulation of a deposit of lime. These pipes probably lasted longer than would have been the case with the plain wrought-iron pipes, because zinc is quite resistant to corrosion, and, where galvanizing is perfect, would prevent the formation of tubercles long enough to permit the coating of lime to form and prevent further corrosion. The galvanizing of commercial pipe is far from perfect, however, and also in making joints the zinc coating is necessarily injured, so that only a partial protection of the iron results. Galvanized stove-pipe has remained in serviceable condition for four months, while plain iron stove-pipe in the same place has been ruined. The galvanizing, however, now shows rust specks all over.

Brass pipe is corroded by hypochlorite of lime solution, but very much less than iron; in fact, very slowly. Tubercles do not form and the pipe becomes coated with a smooth layer of lime that protects the brass from further action. The effect on the flow in this case is due only to the gradual reduction in the size of the duct. It seems reasonable to expect that brass pipe, say 2 in. in diameter, would last two or three times as long as iron pipe, before renewal or cleaning would become necessary. Moreover, the coating in brass pipes could be cleaned out with acid and the pipe be made as serviceable as originally, with threads uninjured, whereas iron pipe so cleaned would be found rough and a great deal damaged.

At Board of Water Supply plants, where a two per cent. solution was used for one month and a one per cent. solution thereafter, bronze float valves are practically perfect after four months' service with a trickle of solution flowing through them, but the seats have become coated with lime and consequently do not close properly. On scraping off some of this coating the bronze appears to be intact. A long brass valve stem in a hypochlorite of lime

solution tank after three months showed general pitting, but to a very slight depth. A brass screen of about No. 18 wire immersed in the solution was destroyed in less than four months, while another, under almost like conditions, has remained in good condition. The screen destroyed was made of very soft brass.

From such observations as were available at the time of designing certain of the Board of Water Supply plants, it was thought that copper of about 20 gage would be a good material for orifice cans, floats, and for lining small tanks. Its value was much overestimated, however, for in one case a copper tank lining was eaten through in less than three weeks; and in another case an orifice can become leaky in about three months. Floats made of No. 22 copper have become leaky in about three months, being badly pitted on all the surface in contact with the hypochlorite of lime solution. The leaky orifice can was effectively repaired with solder which has resisted corrosion very well. It has not been pitted and the only effect upon it that has been noted has been a blackening of the surface.

Tin appears to resist the action of hypochlorite of lime solution very well. Two ordinary tinned copper ball floats, in solutions of one-half per cent. to one per cent. strength, lasted for nineteen months, and one was still serviceable. A similar larger float, in 2 per cent. solution for one month and in 1 per cent. solution thereafter, has been in service for four months and appears to be in perfect condition. There is a slight coating on the surface, but if this is scraped off, bright tin appears underneath.

Bronze orifice plates made of "Worthington anti-corrosive metal" have stood well. The edges are not quite so sharp as originally, but the discharge coefficient has increased during nearly two years of service only about three per cent. Part of this effect can be attributed to wear rather than corrosion.

The effect of hypochlorite on one large metal supply main was to detach the organic matter, which quickly appeared at the reservoirs. The next gaging of the pipe showed an increase in carrying capacity of about six per cent. from the previous year, whereas theretofore there had been an average yearly reduction of about four per cent. in carrying capacity. It is to be expected that similar effects would always be observed in supply mains leading

from reservoirs, for in such cases vegetable growths have a large effect on the carrying capacity. No observations have been made on the corrosive effects in metal mains, but a strong hope seems justified that no material damage will result, since the dose is minute and by far the greater part of the applied chemical is taken up by organic matter in the water before it has a chance to come in contact with the pipe. The point of application of the chemical would, of course, have an effect on the results. A relatively long period between the application of the dose and the entrance of the treated water into the pipe would lessen the tendency to action on the pipe.

Wood is readily affected by hypochlorite solution. Mixing tanks of white pine began to show serious damage within a month, the end grain at the rabbet being affected most and so softened that it could be crushed or scraped out. Storage tanks containing two per cent. solution were not much affected during the same time. All tanks, however, were lined with cement mortar shortly afterwards. Wooden stilling boxes have lasted for nearly two years in solutions of one-half per cent. and one per cent. strength, but at the end of a year and a half the wood was found to be so softened that the edges could be broken off with the hand. Wooden floats boiled in paraffine and coated with a thick layer of paraffine have been used successfully. They appeared to be entirely unaffected after many months of service.

Mr. Edward D. Eldredge.* We have had rather an interesting example of corrosion occur lately in the internal parts of a pump close to the composition valve seat. The cast iron was originally fully an inch thick, but a hole appeared entirely through the iron. The hole was chipped out round, tapped, and a $\frac{3}{4}$-in. pipe plug put in. Not many days after, the plug became loose, the iron being further corroded, the hole was tapped larger, and an inch plug put in. The hole for the inch plug gave an opportunity to reach down with the finger to the under side of the plate, and there were cavities there which indicated that at some parts the iron was not over a quarter of an inch thick. This was in the cylinder of the pump, a part of the main casting, and it made it necessary to condemn the cylinder. I should like to hear any

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* Superintendent Onset Water Company, Onset, Mass.

discussion on the subject as to what was the cause of such a corrosion, my idea being, not that it was electrolysis from any stray current, as such conditions did not exist, but that it was due to the presence of an excess of composition — the subject which Mr. Weston referred to; that the excess of composition in proportion to the amount of iron set up an action there which corroded the iron. The piston, piston rod, cylinder lining, valve seats, etc., were of brass. The case seemed to me to be more marked than any other I had ever known. The new pump will have a cast-iron piston and steel rod. I shall expect any corrosion that may occur to show itself on the iron piston, which can easily be renewed if necessary.

Mr. Samuel A. Agnew.* I do not intend to go into the scientific reasons for this, but I am rather surprised at some of the things Mr. Weston has told us, and I guess there are a number of others who feel the same way. For instance, referring to galvanized iron pipe, I always supposed that we used galvanized iron pipe because the galvanizing was not dissolved in the water the same as the iron was. As I understand from Mr. Weston, it is actually dissolved, but so long as there is any galvanizing there it so saturates the water that the water does not affect the iron. Did I understand this correctly?

Mr. Weston. Locally, yes.

Mr. Agnew. This is rather a surprise to me, because I have often found the pipe eaten into where the galvanizing has been broken off at the ends to the extent that the pipe has started leaking. Now, according to this theory, so long as the galvanizing is there to keep the water saturated with this material, there is no room left for the iron to penetrate the water. I should like to have an explanation so I could understand it a little better.

Mr. Weston. The explanation of that point is rather complicated, as there are two actions going on. First, there is the solution of the zinc in the presence of iron; and then there is the protection of the zinc coating itself, the zinc rust combined with the organic matter. Probably in a great many waters the latter is a much better protection to the zinc than any iron-rust coating is to the iron. After the galvanized coating disappears, the iron

* Superintendent Scituate Water Works, North Scituate, Mass.

beneath the galvanized iron coating goes very much more rapidly than the zinc went, because the iron rust formed does not protect the iron to the degree that the zinc rust protected the zinc. One must not confuse the protective coating idea and the solution idea. Those two things are entirely distinct and they complicate each other. Mr. Eldredge's question I can only answer by mentioning cases where ordinary cast iron, the material composing the pump chamber Mr. Eldredge spoke of, exposed to water containing silica, had become so soft that it could be cut with a knife, most of the iron having changed over from metallic iron to iron silicide. In this case the silica in the water had interchanged with the iron, the iron going into solution and the silica combining with the remaining iron making a soft iron-silicate. There are other similar cases on record. Such cases occur generally in ground or sea water containing a good deal of silica.

One additional word with regard to the organic matter which affects pipe. Organic matter in a great many waters is not in solution, but in a state of finely divided suspension. It is in gelatinous form. When an electric current is passed through water containing this gelatinous matter the latter migrates to the iron, and plates out on its surface just as silver plates on copper in an electric plating bath; this peculiar gelatinous substance is a great protection to all metals exposed to water. On the other hand, if there is present humus matter, or organic matter such as we find in the Dismal Swamp water, that is of an acid character, it acts like the chlorine in bleaching powder or like carbonic acid, interchanging with the iron, and the iron thus freed goes into solution. Thus when we say organic matter, we mean two things, — acid organic matter which corrodes, and gelatinous organic matter which protects.

The President. I would like to ask Mr. Eldredge if his supply is from wells.

Mr. Eldredge. No, it is from a pond which is fed entirely from the bottom, there being no surface inlet or outlet. It is practically natural filtered ground water that has been exposed to the air.

Mr. W. C. Hawley.* Referring to the matter of the deteri-

* Engineer and Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

oration of cast-iron pipe, the original 12-in. main in Atlantic City was laid in 1882. In fifteen or twenty years the character of the metal had changed to such an extent that with a jack-knife you could readily cut into it from one eighth to one quarter of an inch in depth. Before the steel main was laid, in 1901, we took out some sections of the old 12-in. pipe where the action had apparently gone entirely through the shell of pipe.

We have had rather an interesting experience with hypochlorite of lime. We began using it some six or eight months ago, before we completed our filter plant. The galvanized iron pipe through which the solution is fed to the suction well is still in very good condition except where cutting threads on the pipe removed the galvanizing. Ordinary brass is quickly attacked, but a good grade of bronze shows no sign of damage. About the time we began using the lime, we were forced, on account of repairs to the other engine, to run one of our large engines for some months without being able to get into the condenser, which is located on the suction pipe, to examine it or clean it. Our vacuum began to reduce and dropped off from about twenty-six inches to about nineteen inches, but within twenty-four hours after we introduced the hypochlorite the vacuum had increased to about normal. I began to be frightened for fear the hypochlorite might injure the tubes in the condenser, and we shut down long enough to examine them, but found that no damage had been done to the tubes but that they had been thoroughly cleaned of all organic matter and sediment which had collected on them and they were left clean and in good condition.

Mr. William F. Sullivan.* The difference in the ruling prices between plain wrought-iron pipe and galvanized iron pipe is about ten per cent. I would like to ask Mr. Weston if his researches would indicate that that difference in price would be offset by the life of the galvanized pipe.

Mr. Weston. It is difficult to answer Mr. Sullivan's question directly because some waters form a protective coating on the surface of the zinc and others do not. In the case of a water containing little mineral matter and much carbonic acid, for example, a pure ground water, a protective coating would be very slight,

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

the zinc would dissolve rapidly, and galvanized pipe would not pay. On the other hand, most New England surface waters attack zinc very slowly and form good protective coatings. The additional benefit which would accrue from having pipe which does not clog with iron rust is worth the extra price of galvanizing when this kind of water is passed through it. In other words, the character of the water must be taken into consideration; if it attacks zinc rapidly it hardly pays to use galvanized iron pipe with it. If it is like most New England surface waters, like the water of Mr. Sullivan's city, Nashua, for example, it does decidedly pay, because the zinc rust is white, the iron rust is red, and one does not notice the zinc rust in water.

I fear that I did not answer Mr. Agnew clearly enough. The electrolytic action between iron and zinc and galvanized iron pipe is very much localized. If the zinc had dissolved or had worn off one end of the pipe and the iron was exposed, and if the zinc coating some distance from this point was attacked, it would not protect the exposed iron some distance from it. The resistance of the water to the passage of electric currents between distant points is so great that the electrolytic action is usually local. If an ordinary galvanized iron nail be put into pure water stiffened with agar, a jellylike substance, solution of the zinc begins immediately, but only at certain points. The whole length of the nail may be a series of alternate positive and negative points, the solution taking place at the negative points only. Sometimes there are four or five positive points and four or five negative points along the length of a nail three inches long. One would expect to find the same phenomena inside a service pipe, namely, alternate negative or solution points and non-solution or positive points.

Mr. Kuichling. Do they not also interchange and keep changing? What are negative to-day may be positive next week?

Mr. Weston. Yes.

Mr. Kuichling. And for that we have no good explanation?

Mr. Weston. No, sir.

ICE FORMATION.

BY H. T. BARNES, D.SC., MACDONALD PROFESSOR OF PHYSICS AND DIRECTOR OF THE PHYSICAL LABORATORIES, MC GILL UNIVERSITY, MONTREAL.

[*Read September 22, 1910.*]

I have the honor to present in this paper a brief account of the main results of a study for many years of the ice conditions on the St. Lawrence River. I have no doubt many, if not all, the members of the Association have had practical experience of the formation of ice in connection with water works, and I should deem it a great privilege to have discussions from those who have to deal with practical problems.

Being ice bound for so many months of the year, the St. Lawrence has offered favorable facilities for studying ice formation on a large scale. The river is not subject to floods, as are many of the American rivers; its flow is more uniform, but it experiences floods at many places for a short time each winter and spring, due to the accumulation of ice. A royal commission was appointed in 1885 to study the cause of the floods which produced so much inconvenience at Montreal. A very valuable and comprehensive report was issued giving an account of the general ice conditions of the river. A large number of maps were also produced, illustrating the exhaustive ice survey made at the time. The conclusions arrived at by the commission were that the floods were caused by the accumulation of frazil and anchor-ice and the general stoppage of the channel caused by the winter ice pack. They advocated keeping the river clear of ice from Lake St. Louis to tide water, in order to give a free runway for the ice. Much attention was directed to the character of frazil and anchor-ice, and many attempts were made to find some connection between the temperature of the water and the formation of these ice masses. Ordinary methods of measurement were found to yield conflicting results, but the most careful series always showed practically

no deviation of the temperature of the water from the freezing point. This has been the universal experience of all who have attempted to follow the course of water temperature during the winter months. In 1895 I made a serious attempt at the problem employing a very delicate thermometer,* and I succeeded in showing that the temperature was subject to minute variations of the order of a few thousandths of a degree. Thus the total variation of temperature in the water during the winter probably never exceeds one or two hundredths of a degree unless from exceptional circumstances. Yet within the limits of so small a fluctuation tremendous physical effects are produced. Nowhere can one find a more wonderful exhibition of the delicate poising of the forces of nature.

Recent observations made on the river from the decks of the Canadian government ice-breakers, which were kindly permitted by the Department of Marine and Fisheries, have confirmed the earlier conclusions.

In nature we find three kinds of ice formed, — surface ice, frazil-ice, and anchor-ice. The circumstances giving rise to the production of any of these forms are now well understood and easily recognized.

Without going too deeply into the theoretical reasons for many of my conclusions, I wish to point out as briefly as possible what I have found characteristic of each of these forms of ice.

SURFACE ICE.

In a lake or quiet river not flowing with sufficient rapidity to produce serious eddies, we find with the advent of cold weather and the approach of the water temperature to 32° Fahr. that there is a tendency to form ice. Depending to a large extent on the vagaries of climate or direction of wind, the ice forms first along the shores and gradually extends out on all sides. Several conditions must hold before the surface can be entirely covered. The water must be at or very near the freezing point, the air temperature must be at or below the freezing point, and the wind must be practically zero in order that no ripples be produced. The latter

* Fully described in "Ice Formation," New York, John Wiley & Sons.

condition does not occur very often, but when it does the surface becomes covered with ice. Wind then no longer disturbs the surface and the growth of the sheet proceeds at a uniform rate. As long, however, as there are ripples, the surface cannot freeze in a solid sheet. The crystals of ice which are formed with a wind are broken up and prevented from freezing together. Surface waves are exceedingly effective in retarding the ice sheet.

Atmospheric humidity determines very largely the growth of the first ice cover. A dry wind will produce rapid evaporation and a consequent rapid absorption of heat. In a cold atmosphere the air over the water is warmed and is in consequence capable of absorbing more moisture than it can hold when blown away to colder parts. Hence the characteristic steaming of open water or thin ice, which is observed when the atmosphere is in the neighborhood of 10° Fahr. It can be readily shown that air of 25 per cent. humidity will increase the rate of growth of an ice sheet as much as 50 per cent. up to a thickness of about an inch, after which the influence becomes proportionately less as the sheet thickens. A cold, dry north wind blowing over water has a large influence on the formation of ice.

The exact temperature of the water also plays an important part in the formation and growth of surface ice. With water exactly at 32° ice will thicken indefinitely as long as the air temperature is below the freezing point, the rate of growth becoming very small for great thicknesses. It seldom happens, however, that the water is exactly at 32° under an ice sheet; it is usually one or two hundredths of a degree above freezing, and the influence of this is to produce a limiting thickness to which the ice will grow; or, in other words, a balance is finally produced between the heat carried away by conduction through the ice and heat supplied by convective streams of water slightly warmer than 32°, which bathe the under surface of the ice sheet. If the water is higher in temperature, due to bottom streams being deflected upwards by shoals or to warm springs, then no surface ice can form at all. Thus we often observe "air holes" in lakes or rivers otherwise frozen over. Measurements of the temperature of the water in these air holes have shown a temperature higher than existed under the surface ice in the immediate neighborhood.

RATE OF GROWTH OF SURFACE ICE.

As soon as the first thin layer of ice has taken over the surface of still water, the growth proceeds at a perfectly regular rate which may be calculated. The position of the first crystals are along the surface of the water, but as soon as the formation proceeds as a result of conduction of heat through the ice, then the ice crystals are all orientated with their principal axes at right angles to the water surface. It has been indicated by previous experiment that an ice crystal conducts heat best in the direction of the principal axis, and the fact that all such crystals are turned so as to transmit the heat of the water most readily indicates that this is so. The difference between conduction ice and conglomerate ice — that is, ice formed by the freezing together of irregular masses — is very great when considered with reference to their power of disintegration. Salt-water ice is a notable example of this, and the masses of such ice not being regular in crystalline structure take a very long time to melt. It is only conduction ice that forms on a smooth lake or river, the conglomerate ice being produced along the shores and in the bays of rivers flowing too swiftly to freeze over entirely, by loose masses of floating ice being blown inshore by the wind and freezing together.

There has been very little if any scientific work done in studying the rate of growth of surface ice, and the data available are practically useless. The question in any particular case is complicated by variable meteorological conditions, and the opportunity to accurately study the natural rate of growth of ice is not often at hand. Some exceedingly valuable results were obtained by my assistant, Mr. King, last winter while at work on the government ice-breaker *Lady Grey*. A quiet bit of water next the ship in the Louise Basin at Quebec was studied during a period when the tide was not running rapidly. Ice commenced to form over this water, and for a considerable time Mr. King withdrew, at intervals, portions of the ice sheet for measurement. This was kept up until an adverse wind and change of tide swept the whole sheet away. Nevertheless the observations were made with great accuracy, and, what is most valuable, simultaneously with observations by the microthermometer of the temperature of the water, the humidity, and the air temperature. We have spent a great

deal of time analyzing these results, and while we feel that more extended observations are necessary to verify and support the various points raised, yet the matter is of so much interest and importance that it warrants more extended observations being made. It is not possible in this paper to give an adequate description of the mathematical analysis necessary to arrive at the various conclusions, but this will be set forth later in another place.

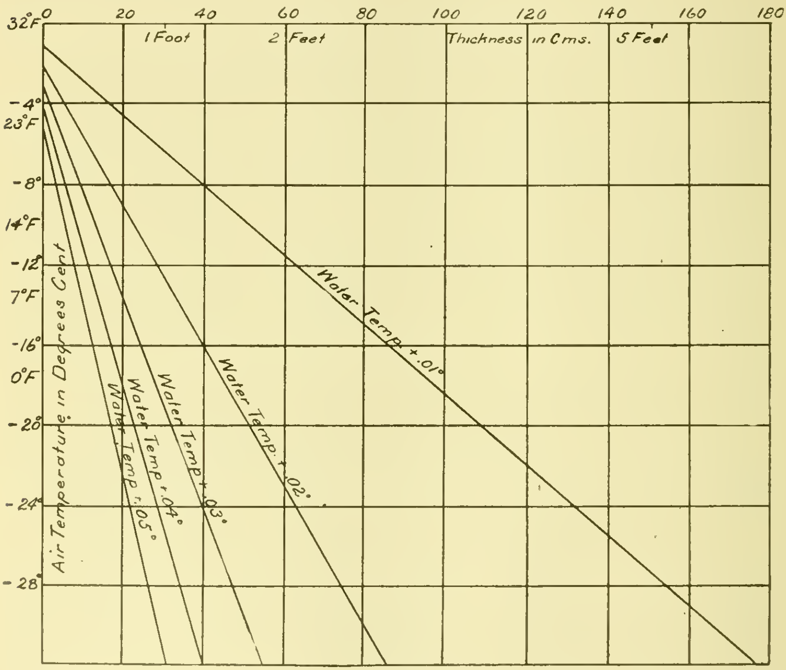

FIG. 1.

The main factor in surface ice formation is the conduction effect, but the rate of growth is affected by convection currents in the water, humidity of the air, which influences the evaporation, and the velocity of the air currents over the ice. Radiation is a small factor which comes into the calculations, both a gain of heat from the sky and loss of heat from the ice surface to the air. Accumulations of snow on the surface will produce an uncertain factor, but

nevertheless an important one which may be corrected for when the depth of snow is known.

Taking conduction alone, a theoretical expression of the type

$$\frac{K}{\rho L}\int_0 \theta dt = x\left(lo + \frac{x}{2}\right)$$

can be readily deduced. In this K is the conductivity of ice, ρ is the density of ice; L is the latent heat of fusion; θ, the temperature of air; x, the distance the ice has attained at a time t, and lo, an expression giving the boundary conditions between ice and water.

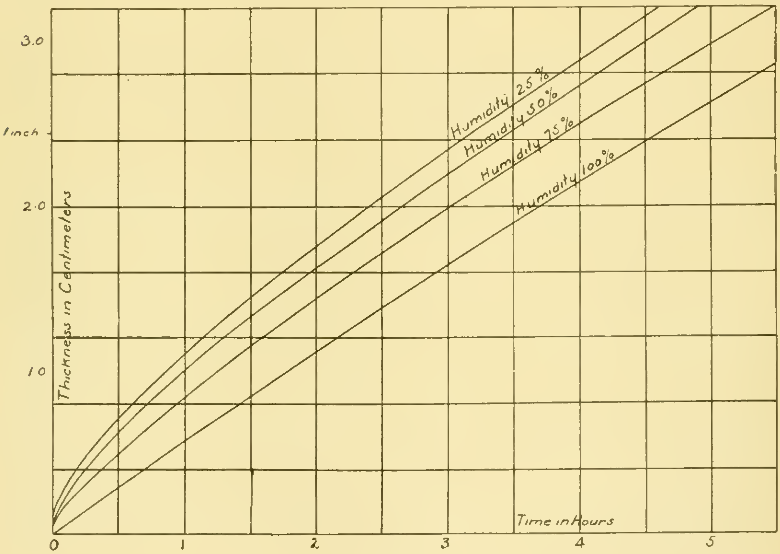

FIG. 2.

Instead of deducing a general equation with terms involving all the quantities which enter into the growth of ice, it is better to take each separately and determine its effect on the general equation. Thus the fact that water under the ice is usually one or two hundredths of a degree above freezing means that the convection currents bring about the limiting thickness. It is possible to arrange in the form of a diagram, Fig. 1, a simple means of finding the limit-

ing thickness to which surface ice will grow, having given the condition of mean air and water temperature. The condition of no ice may exist and the boundary showing the limit of the ice is shown where the lines cut the vertical axis of temperature.

The effect of evaporation I have already discussed. Fig. 2 illustrates the effect of different degrees of humidity on the rate of growth of ice. The effect of radiation on the growth of surface ice is small and not easily determined, and may for simplicity be included with that due to convection; but, although so important a factor in the formation of anchor ice, it is unimportant considered with reference to producing surface ice growth.

FRAZIL ICE.

Wherever a river flows too swiftly for surface ice to form into a sheet, it remains disintegrated in small crystals and is carried down by the current. On account of the smallness of the crystals they have little buoyancy and are, therefore, easily swept under by currents. The amount of frazil, as such ice is called, that is formed depends somewhat on the mean air temperature, but more on the degree of agitation of the water. Thus in rapids where the water tumbles over rocks and is otherwise intimately mixed with the cold air, a great deal of frazil is produced, which becomes troublesome at times and causes winter and spring floods on many rivers. It is swept by currents under the surface ice which is formed in the quieter parts of the river, and then floats up to the underside of the surface sheet and freezes, building down great hanging dams that become as impervious to water as so much rock. The natural river channel is restricted and in consequence the winter level is much higher than in summer.

I have shown* that this ice is formed most rapidly on the surface, but it appears also throughout the body of the river when the water is supercooled. The supercooling is never more than a few thousandths of a degree, but notwithstanding this it produces great physical effects. It is during such a time that the ice becomes adhesive, agglomerated, and produces trouble to the operators of water powers. The strength and tenacity of the frazil as

* "Ice Formation."

long as the temperature remains below the freezing point is enormous. It wants but the very smallest change of temperature in the water, however, to make it soft and spongelike and easily disintegrated.

The sun is the most powerful agent in imparting the necessary small fraction of temperature to the water to relieve ice troubles. Thus water wheels which have been securely cemented during the night are soon running again the next day when the sun comes out.

Artificial methods of heating have been developed which have proved remarkably successful. The most effective methods are those of Mr. John Murphy, E.E., of Ottawa, who has been studying the problem for many years. There is now no reason why any power plant operated by hydraulic means should suffer from ice troubles. This has been brought about through a careful study of the physical laws underlying the formation of ice.

ANCHOR-ICE.

The formation of ice on the bed of a river which is not frozen over has been observed for many years. Many names have been given to this ice. In America it goes by the name of anchor-ice, but in Europe by bottom or ground ice. There has been much discussion over the cause of the formation of this ice. It has now been widely accepted that it grows on the surface of objects immersed in water which is slightly supercooled and flowing too fast to freeze over. On clear, cold nights it is found growing more rapidly than on cloudy ones, and it is observed to form on dark rocks faster than on light-colored ones. Terrestrial radiation is, therefore, responsible for much of the ice, and in addition vast quantities of frazil crystals are frozen to the bottom-ice after having been carried down by currents. With the water above the freezing point no anchor-ice can form, and it has never been observed to grow on the bottom under surface ice. Whenever it has formed previous to surface ice it is dislodged as soon as the cover forms, and rises up to become attached to the underside of the surface sheet.

The sun has a powerful influence in preventing anchor-ice formation, and in melting it off when once it has formed. It is a well-known sight along the St. Lawrence, on a clear, cold morning

in winter, to find great masses of ice rising from the bottom as soon as the sun's rays can penetrate into the water. These masses have been attached to the ground, and by growing in size have exerted greater and greater buoyant force on the rocks. Some of them come up bringing masses of rock with them purely by their own force, but the warm penetrating rays of the sun soon clear the bottom. The masses come up with such force that they often protrude high out of the water, resembling great dark masses of earth, turning white as the water drains out. Soon the whole surface of the river is dotted thickly by these white patches of varying size, floating down with the current. The natives along the river call the masses "haycocks of ice," a name quite appropriate to this form of soft ice. Boatmen on the river are very careful not to go out when the ice is rising, for fear of being surrounded or upset by masses of this ice rising under the boat. In Russia a great deal of time has been devoted to the study of anchor-ice, and the floods caused by the packing of such ice carried down by the currents. In many respects the conditions on the Neva are quite similar to those on the St. Lawrence. It is an interesting point to be observed that the Russian engineers detailed to study the question of winter floods on the Neva have reported along a line exactly similar to the report of the Montreal Flood Commission in 1886. It is pointed out how useless it is to try and combat the ice packs after they are formed, but that every effort should be made in the early stages to prevent them from forming, by means of ice breakers. The water channel must be kept open to allow of a free runway of the ice to tide water, and by this means only can floods be prevented. In conclusion it may be said that there is much to be gained by an active study of ice and methods of prevention on our lakes and rivers. The results have so far been surprising, but a much greater gain may be looked for in the future.

DOUBLE FILTRATION OF WATER.

BY H. W. CLARK, CHEMIST, MASSACHUSETTS STATE BOARD OF HEALTH.

[*Read March 9, 1910.*]

It is a trite saying in regard to surface water supplies that the thing to do is to obtain the best supply of water possible and then filter it, and this is the advice given by many experts upon water supply and water purification and by students of typhoid epidemics. The demand for filtered water or water purified in some way other than filtration has not only been the cause for much scientific research by men who make this subject their life study, but has also encouraged a large number of men engaged in other walks of life, either together or singly, to devise methods that they believe may improve water and which they know will improve their bank account if an unsuspecting public can be persuaded to adopt these methods and their appliances. A number of such schemes come under my observation and investigation nearly every year, and here and there one or another of them has been adopted temporarily. There are to-day two widely known methods of water purification; one, plain sand filtration, and the other, mechanical filtration with the aid of coagulants and such other chemicals as modern experience and necessity suggest may with advantage be used to kill bacteria and thus aid the efficiency of the purification system. We hear a great deal at present about the use of hypochlorite of lime as an aid to mechanical filtration, and its use alone with certain reservoir waters, and the method of treating waters with ozone before filtration is again coming to the front, whether because of its merits or because of its persistent advocates, the future will show. There are, also, so-called electrolytic methods of water purification in which the electric current is stated to act as a bactericide but which in the devices I have examined, simply causes the taking of aluminum from aluminum or composition electrodes and the formation of alumi-

num hydrate, — really an expensive method of coagulation. The purification of water by plain sand filtration is an easy task when the waters treated are not too seriously polluted by suspended matter or organic matter and bacteria, and the question of double filtration only comes to the front when pollution is great or when, owing to the turbidity of the water, it may apparently be of advantage from an economic point of view to subject it to a preliminary filtration or other treatment at a high rate before passing it to the slow sand filtration beds. Double filtration has also been suggested for use where reservoir waters are subject to large growths of organisms causing their characteristic tastes and odors, and such filter plants have been partially constructed at South Norwalk, Conn., and Bar Harbor, Me.

Studies on double filtration of Merrimac River water were begun at the Lawrence Experiment Station in 1894. In the fall of 1893, the Lawrence city filter had been put into operation and it was deemed important to determine just how far the purification so well begun in the city filter could be carried by passing the filtered water through additional sand filters. In the passing years the fact has been lost sight of that when the construction of the Lawrence filter was urged by the Massachusetts State Board of Health, it was stated by the board that double filtration of the river water might be necessary, and in May, 1894, filtered city water was applied to five experimental sand filters which had been previously operated with polluted water. Two of these filters contained less than one foot in depth of sand, one about two feet, and the other two about five feet in depth of sand. The material in the shallow filters was of about the same grade as that ordinarily used in slow sand filters, but that in the two deeper filters was somewhat coarser, more like the sand now used in mechanical filters or preliminary filters intended to be operated at high rates. The three shallow filters were operated at rates of from 2 000 000 to 3 000 000 gallons per acre daily, and the two deep filters were operated comparatively at rates of 2 500 000 and 5 000 000 gallons per acre daily, respectively.

Notwithstanding the fact that this water had passed through the city filter, had been stored about six weeks in the distributing reservoir, and had passed through about two miles of street

mains, during which processes a material reduction had been made in the small numbers of bacteria remaining after its initial filtration, still when the water was filtered a second time through a filter containing but ten inches in depth of sand, a very considerable improvement in its bacterial quality was produced, for as shown in an accompanying table, from 65 to 85 per cent. of the few bacteria in the water applied to these filters was removed. Tests made by adding cultures of special types of bacteria (*B. prodigiosus*) to the applied water showed, furthermore, that the elimination of such test types was even greater, or more than 99.6 per cent.

These early experiments proved that filtration processes could be effectively applied over and over, and that so long as anything remained in the water which could be removed, a further filtration would produce a certain improvement in the quality of the water, and gave rise to the belief that higher rates, or greater economy of operation, might be effected by double filtration methods.

Experimental Filters receiving Filtered Water.

Effective Size of Sand.	Depth of Sand. (Inches.)	Rate. Million Gallons per Acre Daily.	Bacteria per Ccm. in Effluent.	Bacterial Efficiency.
.20	10	2.0	52	45.3
.20	10	3.0	30	72.7
.20	24	3.0	15	86.4
.29	20	2.5	35	68.2
.35	58	2.5	18	81.6
.35	58	5.0	18	81.6

Experiments on double filtration of water even more seriously polluted by sewage than Merrimac River water were made at Lawrence about fifteen years ago. In May, 1896, two filters were put into operation receiving such water, and the average rate of operation of these filters throughout the year was slightly more than 1 000 000 gallons per acre daily. They received water containing twice as much organic matter as was present in the Merrimac River and twenty times as many bacteria. One of these filters was operated continuously and the other intermittently, and the average removal of bacteria was 75 and 92 per cent., respectively. The much greater efficiency of the intermittent filter was due to the great pollution of the water and the necessity,

if good results were to be obtained, of such additional air supply as intermittent filtration gives. During the last four months of their operation, the bacterial efficiency of the filters was 96.5 and 98.5 per cent., respectively. Even then, however, the effluents of these filters contained nearly as many bacteria as were present in Merrimac River water, and refiltration through a secondary filter was begun in September, 1896. This secondary filter was at least three months in getting into good working operation, but at the end of the third month its efficiency was about 90 per cent. and it was producing a water having about 350 bacteria per ccm. when operating at a rate of about 4 000 000 gallons per acre daily. The operation of this filter made it clear that water after a primary filtration was so free from organic matter that a secondary filter gained its normal bacterial efficiency very slowly.

This particular investigation was continued for five years and is summarized in the Lawrence Experiment Station report for 1900, where it is shown that the two preliminary filters during their entire period of operation removed about 98 per cent. of the bacteria present in the polluted water applied, leaving effluents, however, containing several hundred bacteria per ccm., and the secondary filter operating at a rate of about 2 500 000 gallons per acre daily removed 96.5 per cent. of the bacteria in the applied effluents and produced a water containing only 60 bacteria per ccm. With the very polluted water dealt with, the rates of operation were necessarily low, and about three acres of filter surface would have been necessary to produce 1 500 000 gallons of purified water per day. From time to time after this, other investigations of a similar nature were made that I will not summarize here. For the past three years, however, a series of filters has been operated at the station to test the efficiency of such filters when operating under varying rates and the efficiency of double filtration when treating a water similar to that flowing in the Merrimac River at Lawrence. The following table shows the results obtained when filtering Merrimac River water through practically duplicate filters operating at rates of from 3 000 000 to 16 000 000 gallons per acre daily. The results shown in the table are an average of nearly two years' work and of many hundred bacterial analyses of each effluent.

Effective Size of Sand.	Filter No.	Rate. Gallons per Acre Daily.	Bacteria per Ccm. in Effluent.	Bacterial Efficiency.	B. Coli in 1 Ccm. (Per Cent. of Positive Tests.)
.28	A	3 000 000	48	99.1	5.0
.25	B	5 000 000	85	98.4	24.0
.22	C	7 500 000	105	98.1	25.0
.22	D	10 000 000	110	98.0	25.0
.22	E	16 000 000	280	95.0	38.0

Operating at these rates the efficiencies varied from 99.1 to 95 per cent., and the number of bacteria in the respective effluents from 48 to 290 per ccm. In regard to the result of the filter operating at the highest rate and the probable effect of the use of such a water, it can be said that before the city of Lawrence filtered its water supply, the water when passing through the city reservoir, which holds about 40 000 000 gallons, lost about 94 per cent. of the bacteria present, and yet this water caused epidemics of typhoid fever. It will be noticed, also, that the hygienic efficiency, or B. coli removal of the filters, decreased very rapidly as the rate of the filters increased, much more rapidly than the bacterial efficiency. The water applied to these filters contained generally from 100 to 500 B. coli per ccm., while in the effluents from the best filter, only 5 per cent. of the 1 ccm. samples tested for B. coli showed the presence of this germ. The experience of many years at Lawrence has shown that an efficiency such as given by the best filter represented on the table is an absolute protection to a city using such water as that flowing in the Merrimac River and filtered through sand.

The question then arose: Can an equally good result be obtained by double filtration with these two filters operating at such rates that a greater volume of purified water per acre of filter surface can be secured?

During the past three years five double filtration systems have been in operation at the station to answer this question, and the results of three of them are given here. All of these filters were ordinary sand filters containing about 40 inches in depth of sand. In the first system the rates of operation were 10 000 000 and 20 000 000 gallons per acre daily, respectively, the rate of the primary filter being smaller than that of the secondary filter; in the second system the rates were 23 000 000 and 7 500 000 gallons per

acre daily, respectively, the rate of the primary filter being greater than that of the secondary filter; and in the third system, both filters were operated at equal rates, namely, 6 000 000 gallons per acre daily. The net rate of each system was 6 600 000, 6 000 000 and 3 000 000 gallons, respectively; that is, the volume of water filtered per acre of filter surface used. It seemed during the first few months of this work that greater efficiencies could be obtained by double filtration than by single and with the production of a greater volume of purified water per acre of filter. Taken as a whole, however, the results were as follows: Neither the first nor the second system gave results quite equal to the single filters shown on the previous table operating at a rate of 5 000 000 gallons per acre daily; neither did either system give results in coli efficiency equal to the single filter operating at the rate of 7 500 000 gallons per acre daily. With the system, however, operating at a net rate of 3 000 000 gallons per acre daily, the results were practically the same as with the single filter operating at a rate of 3 000 000 gallons per acre daily. It is difficult to state just why this double filtration through much greater depths of sand than in use with the single filter does not always give better results than single filtration. One important reason seems to be, however, that the rate of the primary filter has generally been too great for good bacterial efficiency to occur; yet by this primary filtration the organic matter necessary to cause the secondary filter to be an efficient water purification plant has been removed. While we have some results differing from those presented here, still it does not seem reasonable to assume from all the results of Lawrence work that water of the character of that flowing in the Merrimac River can be purified more advantageously or more economically, as far as net product of filtered water is concerned, by double filtration systems than by a single filter operating at a reasonable average rate.

There is, of course, another reason that has been prominently mentioned for the operation of primary filters, and that is to lessen the area upon which the matter in suspension in the raw water is collected. This is a very prominent feature in the beginning of operation of such systems, especially when the primary filters are operated at rates approximating 100 000 000 gallons

per acre daily. It always seems at first that much can be gained in this way; yet as these systems of double filtration are kept in operation at Lawrence, although the water passing to the secondary filter may remain free from matters in suspension, this secondary filter becomes an efficient biological machine, the sand grains throughout its depth become coated with the gelatinous matter necessary for this efficiency, and eventually these secondary filters at Lawrence require scraping almost as frequently and as deeply as if they were receiving raw water without primary filtration.

This, then, must be the conclusion from our Lawrence work: There is little to gain either in economy in sand removal or sand washing, or in bacterial efficiency, in double over single filtration of polluted water such as flows in the Merrimac River, that is, with an equal or nearly equal production of filtered water per acre of filter surface. We realize, of course, that each water presents a separate problem, and Lawrence results are not universally applicable.

SOME WATER-WORKS STATISTICS AND TYPICAL DATA SHOWING RATE OF ACQUISITION OF INCOME FOR DOMESTIC SERVICE BY DIFFERENT CLASSES OF RESIDENTIAL PROPERTY.

BY FRANK C. JORDAN, SECRETARY OF THE INDIANAPOLIS WATER COMPANY.

[*Read September 22, 1910.*]

A month or two ago, Mr. Leonard Metcalf requested the writer to prepare a paper for your Association on the topic "Statistics of the Growth of Income." What he had in mind, I believe, was not the general growth of income of water-works plants, but more particularly the growth of income from domestic service upon individual lines, such lines to be fairly representative of the different sections of a city.

From the standpoint of investment, there are always, in connection with water-works service, districts which do not contribute their share of income, and these districts must be taken into account in making up a general average or in determining proper rates for domestic service. Before giving the results of the studies and investigations, I wish to state that I have called upon and addressed several of the water departments and water companies throughout the Central West but have been unable to obtain any information of value from them along this line, the general statement being that the growth of income on individual lines in the residential districts is usually slow. For this reason we shall be unable to make comparisons which would make this paper more valuable.

The writer has selected pipe-lines in different districts in the city of Indianapolis, Ind., the income from which is assumed to be about the average, or typical of the assumed classification. In making this study, the city naturally divides itself into about the following districts:

1. The cheap district in the outlying portion of the city.

2. The district between middle and cheap class in the outlying portion of the city.

3. The district between middle and cheap residential in the heart of the city.

4. The cheap residential district in the heart of the city.

5. The high-class residential district annexed to the city after the district has been very well built up.

6. The best residential district in the outlying portion.

7. The best residential district in the heart of the city.

As before stated, this paper will deal with one city only, viz., the city of Indianapolis and the Indianapolis Water Company, with which the writer is connected. This company has in its distribution system 325 miles of pipe, the average diameter of which is in excess of 10 inches; 25 000 taps in service supplying between 29 000 and 30 000 dwellings, business blocks, factories, etc. In this connection we wish also to state that the rates charged for water, which have a direct influence upon income, are somewhat less in Indianapolis than those of the average city of its size supplying water under like conditions. We have on our lines, in round numbers, 55 000 buildings of various kinds, of which 55 per cent. are supplied with water by our company. From what we are able to learn from other cities similarly situated, we find that this percentage is lower than in the average city of our class.

On the first district mentioned above, viz., the cheap district in the outlying portion of the city, we found that the revenue per mile of pipe at the end of the first year was $140; at the end of the second year, $200, and that there was very little change in this revenue during the fifteen years following the laying of these lines.

On the lines in the second district, viz., that district between the middle and cheap class in the outlying portion of the city, we found that the revenue was $170 at the end of the first year; at the end of the second year, $260; at the end of the third year, $300; at the end of the tenth year, $340, and that this increase of rate was maintained during the years following the laying of these lines.

On the lines in the third district mentioned, that district between the middle and cheap residential in the heart of the city, it was found that the revenue per mile of pipe at the end of the first year was $250; at the end of the second year, $380; at the end of the

fifth year, $610; at the end of the tenth year, $750, and at the end of the fifteenth, $850.

The growth in income in the fourth district, or the cheap residential district in the heart of the city, was found to be fairly satisfactory. The revenue per mile of pipe in this district was $310 at the end of the first year; $560 at the end of the second year; $740 at the end of the third year; $1 020 at the end of the fifth year, after which the growth was not so marked.

On the lines in the high-class residential district annexed to the city after having been fairly well built up, we found a satisfactory growth, the revenue being $360 at the end of the first year; $560 at the end of the second year; $860 at the end of the fifth year; and this rate of increase was maintained during the years following the laying of these lines.

These investigations indicate that the best residential district in the outlying portion of the city contributes more that the average share of the expense of supplying water. The revenue on the lines in this district was $400 at the end of the first year; $670 at the end of the second year; $1 260 at the end of the fifth year; $2 200 at the end of the tenth year. These lines show a steady increase from year to year.

The average revenue on lines in the best residential district in the heart of the city at the end of the first year was $800; at the end of the third year, $1 570; at the end of the fifth year, $1 930, after which the growth was exceedingly slow for the next ten years, during which time the property was changing from a residential district to a district of flats and apartment houses, with some of the better class of boarding houses. Following this transitory period, the revenue began to increase, reaching $3 060 per mile at the end of twenty years.

It will be noted from Fig. 1 that the growth of income on all lines in outlying districts is slow for the first few years, but the growth is fairly constant throughout the periods as shown; also that the growth of income in the central or thickly populated part of the city is rapid in the beginning, but after the first four or five years there is but a slight increase of income. The reason for this will be apparent to the water-works superintendent or engineer from the fact that in the outlying district the houses are more or

less scattered in the beginning and the income increases according to the increased building along the service line. It will be seen further that the income of but few districts is equivalent to the fixed charges on the lines laid, for the first two or three years; also that the poorer districts do not pay the fixed charges on the

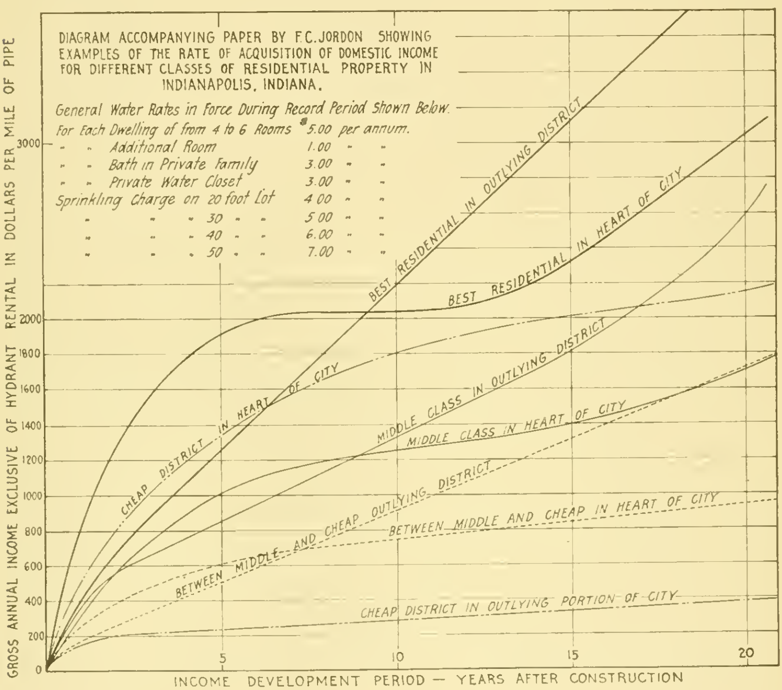

FIG. 1.

lines even after the lines have been laid for ten or fifteen years. This point is frequently overlooked in connection with proposed extensions, as, on account of fire protection, it is necessary, to a certain extent, that all parts of the city shall be served.

The variation in the number of consumers on these lines in the districts is an interesting study. In the best residential district, we are supplying 87 per cent. of the properties adjacent to our lines, while in some of the poorer districts we are supplying only from

8 per cent. to 12 per cent. A map showing the percentage of properties supplied in different districts has been of considerable value to us, particularly regarding the advisability of laying certain proposed extensions.

In Mr. Metcalf's letter to the writer, it was suggested that in connection with the notes on the growth of income, it would probably be of interest to make some mention of our tabulation of water rates. In 1908 the company published a tabulation of water rates in the various cities in the United States. We recently received at our office the latest schedules from the various water companies and departments throughout the United States. The changes in rates and the changes in the attitude of water-works managers regarding some of the important issues were interesting. Practically all of the cities which have recently installed filtration plants have found it necessary to increase their rates to take care of the increased expenditures due to interest on capital investment and to added cost of operation. This is especially true in regard to Columbus, Ohio; Pittsburg and McKeesport, Pa.; Louisville, Ky., etc. In the annual reports of almost all of the companies some mention is made of the desirability of having a reasonable charge for standing ready to serve, and it seems to be the concensus of opinion that all of the cities will finally agree to the fairness of such a charge which will assure the water companies a sufficient revenue to pay the fixed charges on the lines. In going through the schedules we found very few changes in flat rates, it being generally conceded that a rate of $18.00 per year, under ordinary circumstances, is reasonable for water service for a house of six or seven rooms with all the modern conveniences in the way of bath, toilet, laundry trays, sprinkling connection, etc. A number of the cities have made slight changes in their meter rates, and a revision of the tabulation shows that the average maximum rate per one thousand gallons for water by meter measurement is 22.8 cents and the minimum rate is 9 cents. The Manufacturers' Association of St. Louis recently tabulated some information from 23 cities and found that the average minimum rate was 7 cents per one thousand gallons. Their tabulation, however, took into account only the larger cities such as Detroit, Cleveland, Buffalo, New York, etc. In making a study of the schedules of

rates in connection with the reports of the various departments which give an idea of the problems confronting water departments in these various cities, it becomes apparent that it is obviously unfair to strike an average water rate for all cities and then limit a certain city to that rate. A comparison of rates will be found to be of considerable interest, but the fact must be borne in mind that each city has its individual conditions which must be given due weight, and a rate which is fair in one city may, on account of different conditions, be absolutely unfair in a neighboring city.

In reading the various messages from the mayors of the cities to their respective water departments, it will be noted that the municipalities are reaching the conclusion that the first and foremost essential is the furnishing of a first-class supply of good water suitable both for commercial and domestic purposes, to be followed by water rates sufficient to operate and maintain the plant as a whole, as well as to take care of depreciation, and give a fair return on the investment.

As before stated, the appended tabulation was prepared for purposes of direct comparison.

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons.	
		Municipal.	Private.	House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
Birmingham, Ala.	132 685	..	P	$11.00	$5.00	$4.00	...	....	......	$20.00	$0.30	$0.05
Mobile, Ala.	51 521	M	..	6.50	2.75	1.00	$1.00	....	$4.00	15.25	.15	$.03\frac{1}{4}$
Ft. Smith, Ark.	23 505[1]	..	P	8.00	2.00	2.00	....	....	5.00	17.00	.25	.10
Little Rock, Ark.	45 941	..	P	5.50	4.00	4.00	....	....	8.00	21.50	.30	.05
* Los Angeles, Cal.	319 198	M	..	10.20	1.80	1.80	....	....	4.32	18.12	$.09\frac{1}{3}$	$.09\frac{1}{3}$
San Diego, Cal.	39 578	M	..	15.60	3.00	3.00	....	....	4.80	26.40	.10	.06
San Francisco, Cal.	416 912	..	P	4.32	3.84	2.64	.60	....	8.00	19.40	.33	.16
San José, Cal.	28 946	..	P	9.60	1.80	4.80	....	....	8.00	24.20	...	....
Stockton, Cal.	19 354[1]	..	P	8.40	1.80	1.80	....	....	7.80	19.40	.25	.10
Colorado Springs, Col.	29 078	M	..	12.00	1.00	2.00	....	....	8.00	23.00	.15	.06
Denver, Col.	213 381	..	P	4.30	3.60	3.60	....	....	8.80	20.30	.17	.10
† Pueblo, Col.	44 395	M	..	18.00	6.00	6.00	....	....	No rate	30.00	.25	....
Bridgeport, Conn.	102 054	..	P	6.00	5.00	4.00	....	....	4.50	19.50	.18	.04
Hartford, Conn.	98 915	M	..	All metered			....	....	......	.....	.16	.08
Meriden, Conn.	27 265	M	..	5.00	2.00	3.00	....	....	3.00	13.00	.15	.10
* New Britain, Conn.	43 916	M	..	5.00	3.50	3.50	.50	....	3.50	16.00	.10	.05
New Haven, Conn.	133 605	..	P	5.00	3.00	3.00	....	....	6.80	17.80	.18	.10
New London, Conn.	19 882[1]	M	..	4.50	2.00	2.00	....	....	12.50	21.00	.16	.06
Norwich, Conn.	19 759[1]	M	..	5.00	3.00	3.00	....	....	3.40	14.40	.27	.06
Waterbury, Conn.	73 141	M	..	5.00	2.00	3.00	....	....	3.00	13.00	.20	.10
Wilmington, Del.	87 411	M	..	5.00	3.00	2.00	1.00	1.00	3.00	15.00	.10	$.04\frac{3}{4}$
Washington, D. C.	331 069	M	..	.....	....	....	....	....	......	.....	.04	.04
Jacksonville, Fla.	57 699	M	..	All metered			....	....	......	.....	$.10\frac{2}{3}$	$.05\frac{1}{3}$
Pensacola, Fla.	22 256[1]	..	P	8.00	6.00	6.00	2.00	By meter only		22.00	.50	.15
*Tampa, Fla.	38 524	..	P	8.00	5.00	4.00	2.00	....	8.00	27.00	$.22\frac{2}{3}$	.12
Atlanta, Ga.	154 839	M	..	All metered			....	....	......	.....	.10	.07
Augusta, Ga.	37 826	M	..	5.00	3.00	2.00	1.00	3.00	5.00	19.00	.10	.04
Macon, Ga.	40 665	..	P	6.50	5.00	5.00	3.00	3.00	12.00	34.50	.30	.06
Savannah, Ga.	65 064	M	..	.....	....	....	....	....	......	13.50	$.12\frac{1}{2}$	.08

Alton, Ill.	....	..	P	6.00	4.00	3.00	....	....	4.00	17.00	.28	.06
Aurora, Ill.	29 807	M	..	All metered			....	....	......	.....	.48	.05
Bloomington, Ill.	25 768	M	..	All metered			....	....	......	.....	.25	.25
Chicago, Ill.	2 185 283	M	..	.....	....	....	....	....	......	.....	.07	.07
Danville, Ill.	27 871	..	P	5.50	2.50	2.50	0.50	....	6.50	17.50	.25	.10
Decatur, Ill.	31 140	M	..	5.00	3.00	2.50	....	....	6.00	16.50	.10	.04
East St. Louis, Ill.	58 547	..	P	6.00	5.00	5.00	....	....	6.00	22.00	.30	.10
Elgin, Ill.	25 976	M	..	5.00	5.00	2.50	....	....	3.00	15.50	.25	.07
Evanston, Ill.	22 949 [1]	M	..	4.00	3.30	3.30	....	....	3.80	14.40	.16	.08
Joliet, Ill.	34 670	M	..	.....	....	....	....	....	......	14.50	.12	.05
Peoria, Ill.	66 950	..	P	6.00	3.00	3.00	1.50	....	5.00	18.50	.20	.06
* Quincy, Ill.	36 587	..	P	5.40	4.28	4.50	.45	....	7.92	22.55	.45	.06
Rock Island, Ill.	23 009 [1]	M	..	6.00	3.00	3.00	....	....	3.00	15.00	.20	.06
Rockford, Ill.	45 401	M	..	5.00	2.00	2.50	....	....	5.00	14.50	.16	.08
Springfield, Ill.	51 678	M	..	4.00	2.40	2.40	2.40	2.40	8.00	21.60	.25	.06
Anderson, Ind.	25 842 [1]	M	..	4.00	2.50	2.50	2.50	....	4.40	15.90	.15	.05
Clinton, Ind.	....	M	..	5.00	3.00	3.00	....	....	5.00	16.00	.30	.15
Crawfordsville, Ind.	....	..	P	6.00	3.00	3.00	.50	....	3.20	15.70	.30	.10
Elkhart, Ind.	17 501 [1]	..	P	.....	....	....	....	....	......	16.00	.12	.08
Elwood, Ind.	19 232 [1]	..	P	6.00	5.00	5.00	2.00	3.00	5.00	26.00	.25	.07
Evansville, Ind.	69 647	M	..	5.00	2.00	4.00	1.00	2.00	1.50	15.50	.20	.05
Ft. Wayne, Ind.	63 933	M	..	4.40	3.20	2.40	.40	....	6.40	16.80	.10	.06½
Franklin, Ind.	....	..	P	6.00	2.00	2.00	2.00	....	5.00	17.00	.40	.20
Greencastle, Ind.	....	..	P	6.00	4.00	5.00	2.00	2.00	5.00	24.00	.30	.30
Greensburg, Ind.	....	..	P	6.00	3.50	3.00	1.00	....	5.00	18.50	.35	.15
Lafayette, Ind.	19 238 [1]	M	..	5.75	3.50	2.50	1.00	....	5.00	17.75	.20	.06
Linton, Ind.	....	..	P	7.20	3.00	4.00	....	....	6.00	20.20	.35	.07
* Marion, Ind.	24 030 [1]	M	..	4.44	2.22	2.78	.55	....	3.20	13.19	.15	.06
Michigan City, Ind.	17 292 [1]	..	P	2.00	2.00	2.00	3.00	2.00	6.00	17.00	.06	.05
Mt. Vernon, Ind.	....	..	P	5.50	3.50	3.00	....	....	4.00	16.00	.40	.09
New Albany, Ind.	20 628 [1]	..	P	6.65	2.85	1.90	1.90	.95	4.50	18.75	.13½	.04½
New Castle, Ind.	....	M	..	.....	....	....	....	....	......	.....	.10	.08
Noblesville, Ind.	....	..	P	5.00	5.00	5.00	....	....	5.00	20.00	.60	.10
Richmond, Ind.	19 602 [1]	..	P	6.00	5.00	3.00	.50	....	3.42	17.92	.25	.06
Seymour, Ind.	....	..	P	5.75	3.00	3.50	3.00	....	7.00	22.25	.40	.06
Shelbyville, Ind.	....	..	P	5.00	2.50	2.50	2.50	....	3.20	15.70	.30	.10
So. Bend, Ind.	53 684	M	..	4.50	3.00	2.00	1.50	....	3.80	14.80	.12	.08
Terre Haute, Ind.	58 157	..	P	5.00	3.00	3.00	....	....	5.50	16.50	.30	.08
Valparaiso, Ind.	....	..	P	7.00	4.00	4.00	2.00	2.00	5.00	24.00	.30	.15
Vincennes, Ind.	11 393 [1]	..	P	6.00	5.00	5.00	....	1.00	7.00	24.00	.25	.10
Wabash, Ind.	9 944 [1]	..	P	6.00	4.00	3.00	....	....	5.50	18.50	.33	.06⅔
Winchester, Ind.	....	..	P	6.00	3.00	3.00	....	....	3.00	15.00	.25	.07

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910. — *Continued.*

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons.	
		Municipal.	Private.	House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
Burlington, Ia.	25 741 [1]	..	P	$6.00	$5.00	$4.00	....	....	......	$15.00	$0.25	$$0.05\frac{1}{2}$
Cedar Rapids, Ia.	32 811	M	..	6.50	3.00	3.00	....	....	$3.30	15.80	25	.08
Clinton, Ia.	25 577	..	P	6.00	5.00	3.00	....	....	5.00	19.00	.30	.06
Council Bluffs, Ia.	29 292	..	P	7.00	3.00	3.00	....	$2.00	5.00	20.00	.33	.08
Davenport, Ia.	43 028	..	P	6.00	3.50	4.50	$0.90	.90	4.50	20.30	.33	$.11\frac{1}{5}$
Des Moines, Ia	86 368	..	P	4.00	3.00	3.00	....	....	7.50	17.50	.30	.10
Dubuque, Ia.	38 494	M	..	6.00	3.00	3.00	....	....	5.00	17.00	.25	.11
Ottumwa, Ia.	20 548 [1]	..	P	8.00	5.00	5.00	....	....	5.00	23.00	.30	.10
Sioux City, Ia.	47 828	..	...	All metered			....	....	......	.....	.25	.10
Atchison, Kan.	18 871 [1]	..	P	5.60	3.50	3.70	....	....	4.00	16.80	.30	.10
Kansas City, Kan.	82 331	..	P	5.00	4.00	4.50	....	....	6.80	20.30	.25	.05
Leavenworth, Kan.	......	..	P	9.00	5.00	5.00	....	....	10.00	29.00	.50	.20
Topeka, Kan.	43 684	M	..	6.00	5.00	3.00	....	....	6.00	20.00	.50	$.11\frac{1}{4}$
Covington, Ky.	53 270	M	..	All metered			....	....	......	.....	.19	....
Lexington, Ky.	35 099	..	P	All metered			....	....	......	.....	.25	.10
Louisville, Ky.	223 928	M	..	6.00	5.00	3.00	1.00	.50	6.50	22.00	.15	.06
Newport, Ky.	30 309	M	..	6.00	6.00	3.00	2.00	2.00	3.60	22.60	.15	.10
Paducah, Ky.	22 464 [1]	..	P	6.16	3.55	3.30	.70	....	6.50	20.21	.25	.06
New Orleans, La.	339 075	M	..	.....	....	....	....	....	......	.....	.10	.10
Bangor, Me.	23 500 [1]	M	..	5.00	3.00	3.00	3.00	1.00	3.00	18.00	$.07\frac{1}{3}$	$.07\frac{1}{3}$
Lewiston, Me.	26 217	M	..	5.00	2.00	1.50	....	1.00	2.00	11.50	.25	.20
Portland, Me.	58 571	M	..	.....	....	....	....	....	......	.....	$.26\frac{2}{3}$	$.09\frac{1}{3}$
Baltimore, Md.	558 485	M	..	.....	....	....	....	....	......	.....	.08	.04
Boston, Mass.	670 585	M	..	7.00	....	5.00	....	....	5.00	17.00	$.18\frac{2}{3}$	$.10\frac{2}{3}$
Brockton, Mass.	56 878	M	..	All metered			....	....	......	.....	$.22\frac{2}{3}$	$.13\frac{1}{3}$
Cambridge, Mass.	104 839	M	..	4.00	4.00	3.00	2.00	2.00	5.00	20.00	.20	.10
Chelsea, Mass.	32 452	M	..	6.00	....	5.00	....	....	5.00	16.00	$.18\frac{2}{3}$	$.10\frac{2}{3}$
Everett, Mass.	33 484	M	..	7.00	....	5.00	....	....	5.00	17.00	$.18\frac{2}{3}$	$.10\frac{2}{3}$
‡ Fall River, Mass.	119 295	M	..	5.00	5.00	5.00	2.50	....	6.00	22.00	.28	.10
Fitchburg, Mass.	37 826	M	..	5.00	4.00	4.00	1.50	....	4.50	19.00	.18	.04

Gloucester, Mass.	25 989[1]	M	..	6.00	6.00	6.00	3.00	3.00	5.00	29.00	.30	.15
Haverhill, Mass.	44 115	..	..	5.50	3.00	4.00	....	....	5.00	17.50	$.21\frac{1}{3}$	.10
* Holyoke, Mass.	57 730	M	..	3.00	2.00	2.40	....	....	4.80	12.20	$.05\frac{2}{3}$	$.05\frac{2}{3}$
Lawrence, Mass.	85 892	M	..	5.00	3.00	4.00	....	....	3.25	15.25	.20	.08
Lowell, Mass.	106 294	M	..	6.00	3.00	4.00	1.00	1.00	3.00	18.00	$.18\frac{2}{3}$	$.13\frac{1}{3}$
Lynn, Mass.	89 336	M	..	5.00	3.00	3.00	1.00	1.00	4.00	17.00	.20	$.17\frac{1}{2}$
Malden, Mass.	44 404	M	..	All metered			....	....	......	.....	$.21\frac{1}{3}$	$.13\frac{1}{3}$
New Bedford, Mass.	96 652	M	..	All metered			....	....	......	.....	.15	.10
Newton, Mass.	39 806	M	..	All metered			....	....	......	.....	.35	$.04\frac{1}{2}$
No. Adams, Mass.	21 740[1]	M	..	6.00	3.00	3.00	6.00	....	3.00	21.00	.15	.10
Northampton, Mass.	20 220[1]	M	..	6.00	2.00	2.00	....	....	3.00	13.00	.10	.06
† Pittsfield, Mass.	32 121	M	..	5.00	2.50	3.75	....	....	6.25	17.50	.16	.12
Salem, Mass.	43 697	M	..	.....	....	....	....	....	......	.....	.20	$.06\frac{2}{3}$
Somerville, Mass.	77 236	M	..	.....	13.00	....	....	....	4.00	17.00	.16	.16
Springfield, Mass.	88 926	M	..	8.00	4.00	4.00	....	....	5.00	21.00	.30	.07
Taunton, Mass.	34 259	M	..	5.00	3.00	5.00	2.00	....	5.00	20.00	.25	.09
Waltham, Mass.	27 834	M	..	6.00	2.00	3.00	1.00	1.00	6.00	19.00	$.29\frac{1}{3}$	$.17\frac{1}{3}$
Worcester, Mass.	145 986	M	..	6.00	4.00	5.00	1.50	1.50	5.00	23.00	.25	.10
Battle Creek, Mich.	25 267	M	..	6.00	2.00	3.00	....	....	4.00	15.00	.13	.06
Bay City, Mich.	45 166	M	..	6.00	2.00	2.00	1.00	1.00	3.00	15.00	.10	.05
Detroit, Mich.	465 766	M	..	3.20	1.00	1.60	.48	....	1.40	7.68	.05	.03
Grand Rapids, Mich.	112 571	M	..	4.00	2.00	4.00	2.00	2.00	3.00	17.00	.06	$.06\frac{2}{3}$
Jackson, Mich.	31 433	M	..	4.00	2.00	2.00	1.00	1.00	3.00	13.00	.13	$.06\frac{2}{3}$
Kalamazoo, Mich.	39 437	M	..	All metered			....	....	......	.....	.13	$.13\frac{1}{3}$
Lansing, Mich.	31 229	M	..	4.00	2.50	2.50	....	....	2.00	11.00	.40	.05
Port Huron, Mich.	20 464[1]	M	..	4.50	2.00	2.00	1.00	....	6.00	15.50	.10	.06
Saginaw, Mich.	50 510	M	..	6.00	2.00	3.00	....	....	3.00	14.00	.11	.04
Duluth, Minn.	78 466	M	..	6.50	2.00	2.00	2.00	....	4.00	16.50	$.23\frac{1}{3}$	$.06\frac{2}{3}$
Minneapolis, Minn.	301 408	M	..	2.00	3.00	2.50	....	....	3.00	10.50	.08	.08
St. Paul, Minn.	214 744	M	..	3.80	2.00	2.00	....	....	3.00	10.80	$.13\frac{1}{3}$	$.06\frac{2}{3}$
Kansas City, Mo.	248 381	M	..	5.05	3.90	3.70	....	....	6.00	18.65	.25	.07
St. Joseph, Mo.	118 004[1]	..	P	4.50	3.00	3.00	....	....	4.00	14.50	.30	.06
St. Louis, Mo.	687 029	M	..	4.00	2.00	3.00	....	....	2.00	11.00	.25	.08
Springfield, Mo.	35 201	..	P	8.00	3.50	2.00	....	....	5.00	18.50	.25	.10
Butte, Mont.	39 165	..	P	18.00	6.00	....	....	....	12.00	36.00	.50	.20
Helena, Mont.	16 770[1]	..	P	12.00	4.00	4.00	3.00	....	7.50	30.50	.40	.20
Lincoln, Neb.	43 973	M	..	All metered			....	....	......	.....	.15	.10
Omaha, Neb.	124 096	..	P	6.75	3.50	2.50	1.00	1.00	5.00	19.75	.35	.10
So. Omaha, Neb.	26 259	..	P	6.75	3.50	2.50	1.00	1.00	5.00	19.75	.35	.05
Concord, N. H.	21 210[1]	M	..	5.00	3.00	3.00	.50	....	3.00	14.50	$.22\frac{1}{3}$	$.06\frac{2}{3}$
Manchester, N. H.	70 063	M	..	4.50	2.00	2.50	.75	.75	3.50	14.00	$.16\frac{2}{3}$	$.10\frac{2}{3}$
Nashua, N. H.	26 005	..	P	6.00	2.00	4.00	....	....	4.00	16.00	.20	.05

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.—*Continuea.*

City.	Population, 1910.	Water Works. Municipal.	Water Works. Private.	Schedule of Water Rates. House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Meter Rates per 1 000 Gallons. Maximum.	Minimum.
Atlantic City, N. J.	44 461	M	..	$6.25	$2.75	$2.00	$1.75	....	$7.00	$19.75	$0.12	$0.12
Bayonne, N. J.	55 545	M	..	All metered			....	....	......	.....	...	....
Camden, N. J.	94 538	M	..	5.00	3.00	3.00	1.00	$1.00	3.00	16.00	.20	.10
Hoboken, N. J.	70 324	M	..	10.65	2.70	1.80	....	....	2.70	17.85	.18	.11$\frac{1}{3}$
Jersey City, N: J.	267 779	M	..	12.55	4.00	3.00	....	....	5.00	24.55	.20	.10
New Brunswick, N. J.	23 758 [1]	M	..	6.00	4.00	5.00	1.00	2.00	5.00	23.00	.13$\frac{1}{3}$	.13$\frac{1}{3}$
Orange, N. J.	29 630	M	..	5.00	5.00	3.00	2.00	1.00	5.00	21.00	.25	.25
‖ Passaic, N. J.	54 773	..	P	All metered			....	....	......	.....	.30	.10
Paterson, N. J.	125 600	..	P	12.00	....	....	....	....	6.40	18.40	.30	.10
Perth Amboy, N. J.	32 121	..	..	6.00	4.00	3.00	....	....	4.00	17.00	.25	.07
Plainfield, N. J.	19 088 [1]	..	P	6.00	4.00	5.00	2.00	3.00	5.00	25.00	.25	.15
§ Trenton, N. J.	96 815	M	..	4.50	2.25	2.25	.75	.75	2.25	12.75	.08	.08
W. Hoboken, N. J.	35 403	..	P	.....	....	....	....	....	......	.....	.23$\frac{1}{3}$	.15$\frac{1}{3}$
Albany, N. Y.	100 253	M	..	12.00	....	....	....	....	5.00	17.00	.08	.08
§ Amsterdam, N. Y.	31 267	M	..	6.00	2.00	2.50	1.00	....	2.50	14.00	.22$\frac{1}{2}$	.04$\frac{1}{2}$
Auburn, N. Y	34 668	M	..	5.40	2.70	2.70	.90	1.80	3.60	17.10	.33$\frac{1}{3}$	.04$\frac{4}{5}$
Binghamton, N. Y.	48 443	M	..	3.00	3.00	3.00	1.00	2.00	3.00	15.00	.12	.06
Buffalo, N. Y.	423 715	M	..	4.50	1.00	1.50	....	....	......	7.00	.06	.02
Elmira, N. Y.	37 176	..	P	6.00	4.00	4.00	2.00	....	3.00	19.00	.50	.10
Gloversville, N. Y	....	M	..	.....	....	....	....	....	......	.....	.16	.03$\frac{1}{3}$
Jamestown, N. Y.	31 297	M	..	5.00	2.50	2.50	....	....	6.00	16.00	.26$\frac{2}{3}$	.06$\frac{2}{3}$
Kingston, N. Y.	25 908	M	..	5.00	4.00	3.00	1.50	....	5.00	18.50	.22	.06$\frac{2}{3}$
Mt. Vernon, N. Y.	30 919	..	..	.....	....	....	....	....	......	.....	.30	...
New York City, N. Y.	4 766 883	M	..	.....	....	....	....	....	......	.....	.14	.14
Niagara Falls, N. Y.	30 445	..	..	5.00	3.00	3.00	1.00	....	5.00	17.00	.12	.03
Oswego, N. Y.	....	..	..	.....	....	....	....	....	.....	.....	.25	.10
Poughkeepsie, N. Y.	27 936	M	..	3.50	1.50	2.00	.75	1.50	7.50	16.75	.16$\frac{2}{3}$	.04
Rochester, N. Y.	218 149	M	..	All metered			....	....	......	.....	.14	.10
Schenectady, N. Y.	72 826	M	..	4.00	1.50	1.50	....	....	2.00	9.00	.32$\frac{1}{2}$	.09
Syracuse, N. Y.	137 249	M	..	.....	....	....	....	....	......	.....	.18$\frac{2}{3}$	.04$\frac{7}{01}$

Troy, N. Y.	76 813	M	..	5.00	2.00	3.00	....	....	10.00	20.00	.05	.05
Utica, N. Y.	74 419	..	..	.....	....	....	....	....	......	.....	.30	.06
Yonkers, N. Y.	79 803	M	..	All metered			....	....	......	.....	.20	.20
Charlotte, N. C.	34 014	M	..	All metered			....	....	......	.....	.25	.07
Wilmington, N. C.	25 748	..	P	All metered			....	....	......	.....	.26	.08
Akron, Ohio	69 067	..	P	5.63	2.50	2.50	....	....	......	10.63	.16	.08
Canton, Ohio	50 217	M	..	.....	....	....	....	....	......	7.20	.07	.06
Cincinnati, Ohio	364 463	M	..	4.30	2.50	1.50	....	1.00	4.14	13.44	.10	.10
Cleveland, Ohio	560 663	M	..	.....	....	....	....	....	......	.....	.05⅓	.05⅓
Columbus, Ohio	181 548	M	..	6.00	4.00	4.00	2.50	....	5.70	22.20	.16	.12
Dayton, Ohio	116 577	M	..	4.00	2.00	2.50	1.00	2.00	3.30	11.80	.08	.06
Hamilton, Ohio	35 279	M	..	All metered			....	....	......	.....	.16	.06
Lima, Ohio	30 508	M	..	6.00	3.50	2.50	....	....	6.00	18.00	.20	.08
Loraine, Ohio	28 883	M	..	.....	....	....	....	....	......	.....	.20	.07
Mansfield, Ohio	20 142 [1]	M	..	5.00	3.00	3.00	....	2.00	3.00	16.00	.20	.06
Newark, Ohio	25 404	M	..	.....	....	....	....	....	......	.....	.20	.06
Portsmouth, Ohio	20 714 [1]	M	..	6.00	3.00	3.00	1.06	....	......	13.00	.25	.09
Springfield, Ohio	46 921	M	..	4.00	2.50	2.50	2.00	....	5.00	16.00	.10	.06
Toledo, Ohio	168 497	M	..	5.00	3.00	3.00	1.00	1.00	4.00	17.00	.10	.03½
Youngstown, Ohio	79 066	M	..	5.28	2.64	2.64	....	....	3.96	14.52	.20	.08
Zanesville, Ohio	28 026	M	..	5.30	1.00	3.00	2.50	....	4.50	16.30	.06	.06
Oklahoma, Okla.	64 205	M	..	6.00	5.00	3.00	1.00	....	6.00	21.00	.30	.20
Portland, Ore.	109 882 [1]	M	..	6.00	3.00	3.00	....	....	4.00	16.00	.16⅔	.16⅔
Easton, Pa.	28 523	..	P	10.00	3.00	4.00	1.00	...	3.00	21.00	.40	.08
Altoona, Pa.	52 127	M	..	4.80	3.00	2.00	.50	.50	......	10.30	.33	.04
Allentown, Pa.	51 913	M	..	7.50	2.50	2.50	1.00	1.00	4.00	18.50	.12	.06
Chester, Pa.	38 537	M	..	.....	....	....	....	....	......	.....	.30	.04
Erie, Pa.	66 525	M	..	4.00	3.00	3.00	1.00	2.00	3.00	16.00	.20	.04
Harrisburg, Pa.	64 186	M	..	All metered			....	....	......	.....	.16⅔	.02½
Johnstown, Pa.	55 482	..	P	9.75	3.00	3.00	1.00	1.00	5.00	22.75	.27	.05
Lancaster, Pa.	47 227	M	..	6.00	3.00	3.00	1.00	....	5.00	18.00	.12½	....
Lebanon, Pa.	19 404 [1]	M	..	3.00	2.00	2.50	.50	1.00	4.00	13.00	.50	.04½
McKeesport, Pa.	42 694	..	P	8.00	7.50	7.50	4.50	....	8.00	35.50	.26⅔	.09⅓
Newcastle, Pa.	36 280	..	P	7.00	3.00	3.00	1.00	1.00	2.50	17.50	.16	.08
†Norristown, Pa.	27 875	..	..	7.00	3.00	3.00	1.00	1.00	5.00	20.00	.26⅔	.06⅔
Philadelphia, Pa.	1 549 008	M	..	5.00	4.00	4.00	2.50	2.50	5.00	23.00	.04	.04
Pittsburg, Pa.	533 905	M	..	5.25	1.00	3.00	.75	.50	10.00	20.50	.18	.10
Reading, Pa.	96 071	M	..	4.50	2.50	2.00	1.00	....	8.00	18.00	.40	.03
Scranton, Pa.	129 867	..	P	6.00	4.00	4.00	2.00	....	8.00	24.00	.25	.06
Shamokin, Pa.	20 482 [1]	..	P	7.00	3.00	3.00	....	3.00	......	16.00	.26⅔	.05⅛
Wilkesbarre, Pa.	67 105	..	P	.....	....	....	....	....	......	.....	...	....
Williamsport, Pa.	31 860	..	P	6.00	5.00	5.00	1.00	....	6.00	23.00	.10	.05

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.—*Continued.*

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons	
		Municipal.	Private.	House Use 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
York, Pa.	44 750	..	P	$6.00	$4.00	$4.00	$1.00	$1.00	$5.00	$21.00	$0.30	0.06\frac{1}{2}$
Newport, R. I.	27 149	..	P	7.00	5.00	5.00	....	....	10.00	27.00	.40	.25
Pawtucket, R. I.	51 622	M	..		All metered		....	....	......	.....	.30	.06
Providence, R. I.	224 326	M	..	6.00	5.00	5.00	2.00	3.00	5.00	26.00	.20	.20
Woonsocket, R. I.	38 125	M	..		All metered		....	....	......	.....	.30	.10
Columbia, S. C.	26 319	M	..		All metered		....	....	......	.....	.15	.06$\frac{1}{4}$
Charleston, S. C.	58 833	..	P	10.00	4.00	2.00	1.00	3.00	3.00	23.00	.25	.04$\frac{1}{2}$
Chattanooga, Tenn.	44 604	..	P	7.50	6.00	6.00	....	....	6.00	25.50	.25	.08
Knoxville, Tenn.	36 346	..	P	6.40	4.00	4.00	....	....	10.00	24.40	.18	.05
Memphis, Tenn.	131 105	M	..	6.00	5.00	5.00	....	....	10.00	26.00	.24	.10
Nashville, Tenn.	110 364	M	..	9.00	4.00	5.00	....	....	6.00	24.00	.20	.08
Austin, Tex.	29 860	M	..		All metered		....	....	......	.....	.33	.07
Dallas, Tex.	92 104	M	..	8.00	6.00	4.00	....	....	2.50	20.50	.25	.12$\frac{1}{2}$
El Paso, Tex.	39 279	..	P		All metered		....	....	......	.....	.20	.12$\frac{1}{2}$
Ft. Worth, Tex.	73 312	M	..	.....	....	....	....	....	......	.....	.30	.30
Galveston, Tex.	36 981	M	..	6.00	6.00	3.00	3.00	2.00	4.00	24.00	....	....
Houston, Tex.	78 800	M	..	12.00	3.00	6.00	3.00	....	......	24.00	.50	.20
Waco, Tex.	26 425	M	..	7.00	5.00	3.00	....	....	7.20	22.20	.40	.15
Ogden City, Utah	17 165[1]	..	P	6.50	1.00	1.50	....	....	......	.....	.20	.06
Salt Lake City, Utah	92 777	M	..	4.50	1.00	2.00	....	....	6.00	13.50	.10	.03$\frac{1}{2}$
Lynchburg, Va.	29 494	M	..	6.00	3.00	3.00	2.00	....	3.00	17.00	.20	.03
Newport News, Va.	28 749[1]	..	P	10.00	3.50	3.50	....	....	......	17.00	.30	.10$\frac{1}{2}$
Norfolk, Va.	67 452	M	..	5.60	2.40	2.40	....	....	2.40	12.80	.09	.09
Petersburg, Va.	21 810[1]	M	..		All metered		....	....	......	.....	.20	.07
Richmond, Va.	127 628	M	..	4.00	3.50	3.00	....	....	8.80	19.30	.15	.05
Roanoke, Va.	34 874	..	P	9.00	3.00	3.00	1.50	3.00	3.00	22.50	.25	.10
Seattle, Wash.	....	M	..	7.80	2.40	2.40	....	....	......	.....	.26	.05$\frac{1}{3}$
Spokane, Wash.	47 006[1]	M	..	12.00	2.40	2.40	....	....	2.00	18.80	.15	.15
Tacoma, Wash.	82 972	M	..	11.40	2.40	2.40	....	....	4.80	21.00	.40	.11

Charleston, W. Va.	....	..	..	....	....	....	....	....	......	.....	.25	.07½
Wheeling, W. Va.	41 641	M	..	6.00	1.50	6.00	....	....	6.00	19.50	.15	.15
Eau Claire, Wis.	18 981[1]	..	P	6.80	4.00	4.00	2.00	....	6.00	22.80	.30	.08
Green Bay, Wis.	25 236	..	P	6.00	4.00	4.00	2.00	....	6.00	22.00	.40	.20
La Crosse, Wis.	30 417	M	..	5.00	2.00	3.00	....	2.00	5.00	17.00	.20	.04
Madison, Wis.	25 531	M	..	....	....	....	....	....	......	.....	.18	.05
Milwaukee, Wis.	373 857	M	..	All metered			....	....	......	.....	...	.06
Oshkosh, Wis.	33 062	..	P	6.00	2.00	4.00	1.00	....	5.00	18.00	.40	.05
Racine, Wis.	38 002	..	P	4.80	3.60	4.00	1.80	....	4.80	19.00	.30	.06
Superior, Wis.	37 643[1]	..	P	6.40	4.00	4.00	....	....	9.60	24.00	.40	.08

* 10%. † 20%. ‡ Credit $1.50. § 25%. ‖ Less 5%." [1] Population 1906 estimate.

Comparison of the Water Rates of Indianapolis with Those of Cities of the United States having a Population of 20 000 or over.	For Family Use for House of 6 Rooms with Hot and Cold Water at Kitchen Sink.	For Family Use. Bath, Water Closet, Wash Stands, Sinks, etc., Complete for House of 6 Rooms.	For Family Use. Bath, Water Closet, Wash Stands, etc., Complete for House of 6 Rooms; also Sprinkling for Lot of 40-Foot Frontage with Privilege of Sprinkling Roadway.	Meter Rates. Maximum per 1 000 Gallons.	Meter Rates. Minimum per 1 000 Gallons.
Rates in 237 cities where water is supplied by private company or municipal plant	$6.40	$14.09	$18.98	0.22\frac{8}{10}$	$0.09
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 75 cities where water is supplied by private company	7.06	15.75	20.90	.30	.09⅔
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 32 cities having population more than 100 000	6.25	14.24	19.60	.18	.08½
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 162 cities where water is being supplied by municipal plant	6.05	13.34	17.80	.20	.09
Indianapolis rate	5.00	11.00	17.00	.18	.04½

TABLE SHOWING PERCENTAGE OF PIPE OF VARIOUS SIZES IN CITIES OF THE UNITED STATES. — (*Compiled 1908.*)

CITY.	Population according to Gov't Estimate of 1906.	Mileage of Mains Last Report in Our Files.	Percentage of 3-Inch and 4-Inch Pipe in System.	Percentage of 6-Inch Pipe in System.	Percentage of 8-Inch Pipe in System.	Percentage of 10-Inch Pipe in System.	Percentage of Pipe 12-Inch or Larger.
Atlanta, Ga.	104 984	163	5	69	6	5	15
Atlantic City, N. J.	39 544	79	26	21	17	3	33
Baltimore, Md.	553 669	664	40	28	2	12	18
Boston, Mass.	602 278	735	2	34	16	4	44
Buffalo, N. Y.	381 819	504	7	58	1	8	26
Chicago, Ill.	2 049 185	2 073	8	54	22	..	16
Cincinnati, Ohio	345 230	490	30	38	6	13	13
Cleveland, Ohio	460 327	605	6	55	15	7	17
Columbus, Ohio	145 414	210	11	57	17	1	14
Denver, Colo.	151 920	379	17	47	10	4	22
Detroit, Mich.	353 535	709	24	49	11	6	10
Erie, Pa.	59 993	122	27	55	2	..	16
Evansville, Ind.	63 957	77	17	60	8	2	13
Grand Rapids, Mich.	99 794	166	24	39	13	5	19
Jersey City, N. J.	237 952	225	4	60	12	2	22
Kansas City, Mo.	182 376	342	9	51	16	7	17
Louisville, Ky.	226 129	271	23	49	8	1	19
Memphis, Tenn.	125 018	156	16	48	8	7	21
Milwaukee, Wis.	317 903	409	..	73	14	..	13
Minneapolis, Minn.	273 825	331	..	57	17	1	25
Nashville, Tenn.	84 703	110	14	63	6	..	17
Newark, N. J.	289 634	278	10	67	3	4	16
New Bedford, Mass.	76 746	106	15	37	22	8	18
Newton, Mass.	37 475	141	9	56	21	1	13
Philadelphia, Pa.	1 441 735	1 500	3	68	4	6	19
Pittsburg, Pa.	375 082	370	17	50	10	2	21
Providence, R. I.	203 243	363	..	67	16	1	16
Reading, Pa.	91 141	110	12	44	3	12	29
Rochester, N. Y.	185 703	290	24	43	15	4	14
St. Louis, Mo.	649 320	813	2	59	1	1	37
St. Paul, Minn.	203 815	284	5	63	1	..	31
Springfield, Mass.	75 836	157	8	49	17	1	25
Toledo, Ohio	159 980	202	6	70	13	1	10
Washington, D. C.	307 716	437	9	65	5	..	21
Wilmington, Del.	85 140	119	31	19	32	1	17
Average	......	...	13 per ct.	52 per ct.	11 per ct.	4 per ct.	20 per ct.
Indianapolis, Ind.	219 154	293	7 per ct.	48 per ct.	21 per ct.	5 per ct.	19 per ct.

Data regarding Fire Hydrant Service in Various Cities of the United States. — (*Compiled in 1908.*)

City.	Source of Supply.	System whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Adrian, Mich.	Wolf Creek	Reservoir	80 to 100	None	$50.00	...	Metered	None
Akron, Ohio	Wells	Direct	No	80 per cent.	40.00	400	Metered	15 per ct.
Albany, Ind.	Wells	Direct	100	None	.....	821	......	....
Anniston, Ala.	Springs	Reservoir	No	None	50.00	500	......	Very small
Ann Arbor, Mich.	Wells	Reservoir	No	None	45.00 & 40.00	700	Yes	Not any
Ashland, Wis.	Lake Superior	Direct	120	None	61.62	528	......	Ab't 8 p. c.
Alton, Ill.	Mississippi River	Standpipe	....	None	40.00	500	......	....
Atchison, Kan.	Missouri River	Reservoir	None	All fires	40.00	...	None	10 per ct.
Baton Rouge, La.	Deep wells	Reservoir	90 to 100	None	50.00	440	......	None
Belleville, Ill.	Wells	Direct	75 to 100	None	75.00–60.00	450	Yes	1 per ct.
Beloit, Wis.	Springs	Direct	80 to 100	None	60.60–40.00	500	Metered	5 per ct.
Birmingham, Ala.	River	Reserv'r & direct	None	All fires	55.00	1 000	Metered	....
Brainard, Minn.	Mississippi River	Direct	80 to 120	None	66.10	700	No	5 per ct.
Bridgeport, Conn.	Small streams	Reservoir	None	All fires	12.50	...	Metered	2 per ct.
Bristol, Conn.	Small streams	Reservoir	None	None	20.00	...	......	Less than 1
Bucyrus, Ohio	....	Direct	80	None	40.00	600	Some	1 per ct.
Burlington, Ia.	Mississippi River	Direct	120 to 145	None	45.00	...	No	5 per ct.
Butte, Mont.	Mountain streams	Reservoir	None	None	50.00	...	No	....
Charleston, S. C.	Creek	Direct	None	All fires	.....	500	......	10 per ct.
Charleston, W. Va.	Elk River	Direct	100	None	50.00	300	No	....
Chester, Pa.	Delaware River	Reservoir	None	None	40.00	1 000	Yes, al l	None
Chillicothe, Mo.	Wells and river	Direct	65	None	39.50	...	No	1 per ct.
Clinton, Mo.	Deep wells	Reservoir	150	None	.....	600	......	....
Clinton, Ia.	Artesian wells	Direct	100 to 120	None	30.00	450	No	....
Columbia, Pa.	Susquehanna Riv'r	Reservoir	None	All fires	City hydrant	...	......	....
Columbus, Ga.	Springs	Standpipe	None	None	80.00–40.00	600	......	5 per ct.
Cortland, N. Y.	Springs	Standpipe	No	5 per cent.	33.33	500	......	Very little
Council Bluffs, Ia.	Missouri River	Reservoir	140	None	60.00	650	Yes	....
Creston, Ia.	Reservoir	Standpipe	80 to 140	50 per cent.	50.00	400	Metered	....
Danville, Ill.	Vermilion River	Direct	100 to 125	None	40.00	500	No	....
Davenport, Ia.	Mississippi River	Direct	65 to 125	None	38.00	450	Metered	None
Defiance, Ohio	River	Standpipe	No	None	40.00–35.00	500	No	....
Denison, Tex.	....	Standpipe	125	....	79.25	...	......	....
Denver, Colo.	Platte River	Gravity & pumps	No	All fires	25.00–35.00	400	Metered	6 per ct.
Des Moines, Ia.	Underground gal.	Direct	140	None	.....	...	No	33 per ct.
Durham, N. C.	Rivers	Reservoir	90 to 120	None	50.00–40.00	500	No	....

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES OF THE UNITED STATES.

(*Compiled in 1908.*) — *Continued.*

City.	Source of Supply.	System whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Easton, Pa.	Delaware River	Reservoir	No	....	....	...	Metered	....
E. Providence, R. I.	Ten Mile River	Direct & st'ndpipe	130 to 150	None	$20.00	...	Metered	....
Eau Claire, Wis.	Wells	Direct	140	....	54.00–44.00	528	No	5 per ct.
Elkhart, Ind.	Deep wells	Direct	80 to 115	All fires	59.00	500	No	15 per ct.
Elmira, N. Y.	River	Reservoir	No	All fires	....	...	......	....
El Paso, Tex.	Wells	Direct	No	....	52.00	700	Metered	$1\frac{3}{5}$ per ct.
Elwood, Ind.	Driven wells	Direct	100	None	60.00	528	No	$\frac{1}{5}$ per ct.
Eureka, Cal.	Elk River	Standpipe	100	All fires	37.50	612	Metered	$\frac{1}{2}$ per ct.
Freeport, Ill.	Wells	Standpipe	80 to 100	None	50.00	528	No	15 per ct.
Fort Madison, Ia.	Mississippi River	Reserv'r & direct	125 to 140	None	40.00	380	Metered	$\frac{1}{4}$ per ct.
Franklin, Ind.	Driven wells	Standpipe	60	None	40.00	528	No	2 per ct.
Gadsden, Okla.	River	Reservoir	No	All fires	46.16	528	No	....
Green Bay, Wis.	Wells	Reservoir	100	None	37.50	500	No	....
Greensburg, Ind.	Driven wells	Direct	100	None	33.00	500	No	....
Greenville, S. C.	Mountain streams	Reservoir	No	None	40.00–30.00	400	Metered	....
Greenwich, Conn.	Reservoir	Gravity system	No	5 per cent.	25.00	...	Metered	....
Hagerstown, Md.	Mountain reserv'r	Reservoir	....	None	45.00	500	No	None
Hopkinsville, Ky.	Creeks	Standpipe	No	None	40.00–30.00	500	......	5 per ct.
Huntington, W. Va.	Ohio River	Reservoir	No	None	40.00	528	No	....
Iowa City, Ia.	Iowa River	Direct	125	None	45.00–50.00	400	......	5 per ct.
Iron Mount, Mich.	Wells	Reservoir	60–135	None	58.00	500	Metered	5 per ct.
Iron Wood, Mich.	Montreal River	Standpipe	Yes	None	75.00–50.00	450	No	Not large
Johnstown, Pa.	Mountain springs	Gravity system	No	....	25.00	...	Some	1 per ct.
Joplin, Mo.	Creek	Direct	Yes. 80–100	....	22.50	...	No	....
Kankakee, Ill.	Kankakee River	Direct	100	None	....	...	......	1 per ct.
Keokuk, Ia.	Mississippi River	Direct	140	None	50.00	732	No	1 per ct.
Knoxville, Tenn.	Tennessee River	Res. & standpipe	90 to 100	15 per cent.	40.00–45.00	600	Partly	Less th'n10
Kokomo, Ind.	Well	Direct	100	None	25.00	500	No	2 per ct.
Leavenworth, Kan.	Missouri River	Direct and res'rv'r.	No	None	40.00	...	No	....
Lexington, Ky.	Reservoir	Direct	100	None	50.00	300	No	$1\frac{1}{2}$ per ct.
Lincoln, Ill.	Wells	St'dpipe & direct	110	None	35.00	528	No	8 per ct.
Linton, Ind.	Wells	Direct	No	None	50.00	...	No	Very little
Little Rock, Ark.	Arkansas River	Gravity	No	All fires	50.00	528	No	10 per ct.
Long Branch, N. J.	Surface streams	Direct	70 to 80	Partly	25.00	...	Yes	None
Louisiana, Mo.	Mississippi River	Reservoir	No	None	50.00–33.00	300	No	....
Macon, Ga.	River	Gravity	No	All fires	40.00–37.50	500	Metered	None

Manitowoc, Wis.	Wells	St'dpipe & direct	100 to 120	....	65.00–40.00	528	No	....
Mexico, Mo.	Surface	Direct	100	None	55.00–50.00	600	No	....
Michigan City, Ind.	Lake Michigan	Direct	100	5 per cent.	....	400	No	$\frac{1}{10}$ per ct.
Milford, Mass.	Wells and lake	Direct	110	50 per cent.	50.00	300	Yes	None
Moberly, Mo	Dammed creek	Direct	120	None	84.00	500	No	11 per ct.
Mt. Vernon, Ind.	Ohio River	Direct & reservoir	87	....	37.50	500	No	$\frac{1}{4}$ per ct.
Nashua, N. H.	Springs and wells	Reserv'r and direct	100	90 per cent.	30.00	...	Metered	None
New Albany, Ind.	Ohio River	Reservoir	No	None	60.00–50.00	...	Metered	....
Newark, Ohio	River	Reservoir	No	None	48.00–45.00	400	No	....
New Haven, Conn.	Lakes and rivers	....	No	All fires	....	...	No	....
New Orleans, La.	Mississippi River	Direct	No	All fires	60.00–45.00	...	......	....
Newport News, Va.	Streams	Standpipe	....	Less than 50	25.00	...	Metered	....
Newport, R. I.	Brooks	Reservoir	No	All fires	35.00	...	Yes	No data
Noblesville, Ind.	Deep wells	Reservoir	80 to 120	None	33.33	528	No	5 per ct.
Norristown, Pa.	Schuylkill River	Reservoir	No	50 per cent.	....	...	No	....
Norwich, Conn.	....	Reservoir	No	75 per cent.	40.00–15.00	...	No	....
Oconta, Wis.	Wells	Reservoir	100	None	65.00–50.00	400	No	....
Ogden, Utah	Ogden River	Reservoir	120	None	35.00	...	No	10 per ct.
Omaha, Neb.	Missouri River	Direct & reservoir	No	None	60.00	400	Some	12 per ct.
Oneonta, N. Y.	Springs	Reservoir	No	10 per cent.	25.00	...	No	....
Oshkosh, Wis.	Lake Winnebago	Direct	90 to 125	None	40.00–25.00	528	No	....
Oskaloosa, Ia.	Rivers and wells	Direct & st'dpipe	135	None	50.00	645	No	37 per ct.
Owensboro, Ky.	Ohio River	Direct	80 to 120	None	50.00–40.00	300	Yes	....
Ottumwa, Ia.	Des Moines River	Reservoir	No	None	42.00	400	No	5 per ct.
Paducah, Ky.	Ohio River	Standpipe	110	1 per cent.	28.50	400	No	5 per ct.
Paterson, N. J.	Passaic River	Direct & st'dpipe	No	All fires	30.00	400	Metered	....
Pensacola, Fla.	Driven wells	Standpipe	Yes	None	60.00–40.00	528	......	....
Peoria, Ill.	Wells	Reserv'r & direct	No	50 per cent.	41.60–25.00	440	No	15 per ct.
Pine Bluffs, Ark.	Deep wells	Direct	100	None	43.00–40.00	500	No	1 per ct.
Pittsburg, Kan.	Wells	Tank	110	None	46.00–45.00	500	No	6 per ct.
Plainfield, N. J.	Driven wells	Standpipe	No	None	15.00	...	Yes	....
Portland, Me.	Sebago Lake	Gravity	....	All fires	City hydrant	...	......	....
Quincy, Ill.	Mississippi River	Reservoir	No	All fires	45.00–20.00	...	Some	2 per ct.
Raleigh, N. C.	Creek	Standpipe & direct	100	None	32.50	528	No	$12\frac{1}{2}$ per ct.
Rensselaer, N. Y.	Hudson River	Standpipe	125	None	40.00	500	Some	....
Richmond, Ind.	Galleries	Reservoir	110	None	55.00–49.00	500	No	5 per ct.
Roanoke, Va.	Springs	Direct	No	10 per cent.	20.00	...	Metered	None
St. Joseph, Mo.	Missouri River	Reservoir	No	None	40.00	500	No	3 per ct.
San Antonio, Tex.	Wells	Reservoir & direct	90	25 per cent.	....	...	Yes	$33\frac{1}{3}$ per ct.
San Francisco, Cal.	Mt. str'ms & lakes	Reservoir	No	All fires	....	City hydrants	......	....
San Jose, Cal.	Mountain streams	Direct	No	All fires	6.00	City hydrants	Yes	....
Sedalia, Mo.	River & reservoir	Direct	100	None	30.00	528	Yes	$\frac{1}{4}$ per ct.

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES OF THE UNITED STATES.

(*Compiled in 1908.*) — *Continued.*

City.	Source of Supply.	System, whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Seymour, Ind.	White River	Standpipe	100	None	$45.00–$35.00	350	No	2 per ct.
Shamokin, Pa.	Gravity	....	....	None	City hydrant	...	......	....
Sharon, Pa.	Shenango River	Direct	140	None	35.00	...	No	5 per ct.
Shelbyville, Ind.	Wells	Direct	100	None	30.00	528	No	....
Shreveport, La.	River	Direct	No	All fires	50.00–40.00	...	No	....
S. Bethlehem, Pa.	Lehigh River	Reservoir	No	None	25.00	...	Yes	....
Southbridge, Mass.	Hatchet p. & brook	Gravity	No	None	30.00	500	Yes	....
Springfield, Mo.	Springs	Standpipe	No	50 per cent.	40.00	600	No	2 per ct.
Stockton, Cal.	Wells	Direct	No	75 per cent.	12.00	...	Metered	None
Streeter, Ill.	River	Direct	100	....	45.00–35.00	590	No	14 per ct.
Sunbury, Pa.	Lit. Shamokin cr.	Direct	100	....	18.00	...	No	None
Superior, Wis.	Wells	Direct	120	Small per ct.	40.00	528	No	....
Tampa, Fla.	Wells	Standpipe	110	All fires	35.00	400	Metered	None
Texarkana, Ark.	Wells	Direct	80	30 per cent.	30.00	400	Metered	2 per ct.
Uhrichsville, Ohio	Creek	Reservoir	No	None	40.00	500	No	....
Valparaiso, Ind.	Flint Lake	Direct	90	None	50.00	500	Yes	....
Vincennes, Ind.	Wabash River	Standpipe	No	None	33.33–40.00	450	No	....
Wabash, Ind.	Wells	St'dpipe & direct	130	None	38.00	528	Metered	....
Warren, Ohio	Mahoning River	Standpipe	120	None	45.00–25.00	528	......	....
Washington, Ind.	White River	Standpipe	120	None	35.00	...	No	6 per ct.
Washington, Pa.	Impounding dams	Reservoir	No	None	40.00	...	Metered	None
Waterloo, Ia.	Deep wells	Direct & st'pipe	100	None	35.00	400	......	....
Williamsport, Pa.	Mountain streams	Direct	No	10 per cent.	City hydrant	City hydrants	Yes	....
Wilmington, N. C.	River	Standpipe	120	5 per cent.	50.00	...	Yes	15 per ct.
Winchester, Ky.	Impounding res.	Direct & st'pipe	115	None	40.00	400	Yes	....
Winfield, Kan.	Walnut River	Reservoir	No	None	57.00	600	No	1 per ct.
York, Pa.	Surface streams	....	No	All fires	....	City hydrants	No	5 per ct.
Indianapolis, Ind.	Wells and filter plant	Direct	120	5 per cent.	45.00	500	Practically nothing	10 per ct.

NUMBER OF FEET OF PIPE TO EACH FIRE HYDRANT IN VARIOUS CITIES OF THE UNITED STATES.

(*Compiled in 1908.*)

CITY.	Population According to Gov't Estimate of 1906.	Mileage of Mains.	Number of Fire Hydrants.	Number of Feet of Pipe to Fire Hydrants.
Denver, Colo.	151 920	500	3 200	790
Wilmington, Del.	85 140	119	882	710
Atlanta, Ga.	104 984	180	1 668	570
Augusta, Ga.	43 125	60	750	420
Savannah, Ga.	68 596	67	663	540
Aurora, Ill.	26 823	59	499	620
Chicago, Ill.	2 049 185	2 073	21 183	516
Decatur, Ill.	24 727	45	465	511
Peoria, Ill.	66 365	100	1 200	440
Terre Haute, Ind.	52 805	70	928	398
Burlington, Ia.	25 741	32	335	505
Davenport, Ia.	40 706	75	668	590
Des Moines, Ia.	78 323	130	1 400	490
Kansas City, Kan.	77 912	58	464	660
Paducah, Ky.	30 329	36	424	448
Orange, N. J.	26 493	40	400	528
Paterson, N. J.	112 801	125	1 337	493
Auburn, N. Y.	32 963	70	600	616
Binghamton, N. Y.	43 785	80	800	566
Buffalo, N. Y.	381 819	516	4 891	557
Gloversville, N. Y.	18 624	33	289	603
Rochester, N. Y.	185 703	325	3 500	490
Schenectady, N. Y.	61 919	176	2 769	299
Troy, N. Y.	76 513	104	1 024	536
Yonkers, N. Y.	64 110	103	1 111	490
Cleveland, Ohio	460 327	676	7 966	448
Columbus, Ohio	145 414	210	1 740	630
Dayton, Ohio	100 799	152	1 527	525
Hamilton, Ohio	27 670	43	425	534
Toledo, Ohio	159 980	215	1 650	688
Allegheny, Pa.	145 240	200	1 789	590
Philadelphia, Pa.	1 441 735	1 500	14 311	552
Pittsburg, Pa.	375 082	402	3 753	565
Reading, Pa.	91 141	109	909	633
Boston, Mass.	602 278	743	7 772	505
Fall River, Mass.	105 942	101	1 153	462
Cambridge, Mass.	98 544	128	1 046	646
Holyoke, Mass.	50 778	82	659	657
Lowell, Mass.	95 173	140	1 271	581
Lynn, Mass.	78 743	138	825	883
New Bedford, Mass.	76 746	106	1 105	508
Somerville, Mass.	70 798	91	1 018	472
Springfield, Mass.	75 836	156	1 174	701

NUMBER OF FEET OF PIPE TO EACH FIRE HYDRANT.—*Continued.*

CITY.	Population According to Gov't Estimate of 1906.	Mileage of Mains.	Number of Fire Hydrants.	Number of Feet of Pipe to Fire Hydrants.
Taunton, Mass.	30 953	82	877	494
Detroit, Mich.	353 535	709	4 752	790
Grand Rapids, Mich.	99 794	165	1 547	563
Jackson, Mich.	25 360	72	600	633
Minneapolis, Minn.	273 825	342	3 893	464
St. Paul, Minn.	203 815	285	2 658	566
Kansas City, Mo.	182 376	342	4 024	448
St. Joseph, Mo.	118 004	115	895	678
St. Louis, Mo.	649 320	813	9 298	462
Lincoln, Neb.	48 232	67	568	623
Omaha, Neb.	124 167	235	1 991	667
Atlantic City, N. J.	39 544	65	670	501
Jersey City, N. J.	237 952	224	2 331	508
Woonsocket, R. I.	32 994	53	624	441
Charleston, S. C.	56 317	59	605	510
Nashville, Tenn.	84 703	110	931	624
Dallas, Tex.	52 793	100	800	660
Galveston, Tex.	34 355	31	460	356
Ft. Worth, Tex.	27 096	85	876	510
Average	174 355	231	2 257	555
Indianapolis	219 154	293	2 294	674

DISCUSSION.

MR. LEONARD METCALF.* I want to say one word with regard to the third table. It was prepared at the time that negotiations were pending with the city for the making of a new hydrant rental contract. The statistics were obtained by correspondence, tabulations were made, and the data were subsequently submitted, by Mr. Jordan, if I remember rightly, to the men who had furnished the data. All of that correspondence was thrown open to the city officials and any interested parties, as well as to the officials of the water company. I glanced over more or less of it myself, and I have every confidence in its accuracy. I know that the results were accepted by the city as being thoroughly credible and easily subject to verification.

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

Mr. W. C. Hawley.* This paper shows that for a considerable period of time in most of the cases the company was doing a losing business on the extensions of its distributing system, and it would be interesting to know on what basis these extensions were made. From the figures given it appears in some cases that for several years the revenue per mile was not sufficient to pay interest, depreciation, maintenance, and taxes on the cost of the extension alone, to say nothing of bringing in a revenue to cover the furnishing of water and the other operating and general expenses of the plant. The query is, How can a company reasonably be expected to do business on such a basis? In the case of a municipal plant, with the taxing power of the municipality behind it, extensions are generally made with very little attention to the revenue to be derived therefrom. In the case of a private corporation, it is very different. Such losses must either go to increase the ultimate going value of the concern, or else the rate or rates for water must be enough higher upon all the consumers who are supplied by the company to cover the losses on these extensions.

It might be interesting if we could get the views of various members and statements from various municipal as well as privately owned water works as to the requirements of each for making extensions to reach new consumers.† In the case of our company, we expect a return of at least 15 per cent. per year on the cost of making an extension. We figure that 15 per cent. barely covers interest, depreciation, maintenance, taxes, and the cost of furnishing the water, without leaving any profit. In cases where there are no consumers ready to take water, as, for instance, when some real estate project is being boomed, we ask the parties interested to advance the entire cost of making the extension. The company then lays the pipe and returns to those who have advanced the money the amount of which our minimum rate is 15 per cent. per year for each *bona fide* consumer who takes a supply of water. For the purpose of comparison of this method with the revenues stated in Mr. Jordan's paper, assume that an

* Chief Engineer, Pennsylvania Water Company, Williamsburg, Pa.

† At the November, 1909, meeting, a committee was appointed to report on the conditions under which extensions of water mains are made by town-owned water supplies. Journal N. E. W. W. Association, Vol. XXIII, p. 450. — Ed.

extension of a mile of pipe costs $5 000. Fifteen per cent. of this amount would be $750, and if the municipality is generous and orders the setting of five fire hydrants on this mile of pipe at, say, $40 per year each, or a total of $200 for fire protection, the domestic revenue thus required is $550. This, if we assume a minimum rate of $10 per year per tap, would require 55 taps, and on anything less than this, the company is doing a losing business.

Mr. Leonard Metcalf. I want to echo what Mr. Hawley has said. It seems to me that he has touched upon a point which is entitled to very serious consideration in the operation of water works. It is undoubtedly a fact that many extensions laid by water companies or municipalities do not earn an adequate return for several years, that is, for many years after construction. That, of course, does lead to an increased going value of the plant, and it seems to me that that fact very effectually meets what I believe to be an error in the position of the Wisconsin Public Service Commission, on the interpretation of going value. It seems to me that under normal circumstances the going value of any plant must increase from year to year, and that the correct measure of going value is not the cost of advertising and the cost of acquisition of any business, in the sense which has been used by the Wisconsin commission.

Mr. Hawley's statement immediately brings one face to face with this question: What shall the policy of the city be with regard to its charge for franchise and the limitation of the conditions under which the public service corporation shall operate? Shall the city make the public service corporation a source of income, or provide such conditions that the public service corporation can render the largest measure of service at the smallest cost, and then by a suitable system of inspection see to it that the city shall get what it should from the company? Of course, if you make the conditions under which the company operates as easy as possible, the company can borrow money at a low rate of interest and, having correspondingly smaller charges to meet than if it were paying a heavy franchise tax, for instance, the service can be more readily extended to outlying districts of the city. That should be of advantage to the city. Under the other policy, the heavier the charges which the company has to meet, the greater

the burden, the less likely will it be to meet the growing needs of the city in the outlying districts. Of course I recognize the fact that in many cases companies may not have been as liberal as they should have been, and the city has felt that the only way in which it could retaliate was by increasing the burden on the company, or, rather, by getting an income from the company through a franchise tax or some similar means. I believe, however, that that is, after all, only a system of taxation, and while it may be a good one, as it can be more readily levied, more equitably levied, than some other systems of taxation, fundamentally it does not seem to me right. It seems to me that the best interests of the city are subserved when the conditions of operation are made as easy as possible, and when the service can be extended as rapidly as possible by the company.

Mr. William F. Sullivan.* There is one source of income that is of interest to many water-works managers of both municipal and privately owned plants, and that is the hydrant rental. Some municipally owned water works do not make any charges for hydrants, others only a nominal amount covering installation and other expenses. In private companies, whenever there is a renewal of a hydrant contract, it is generally brought before the public and they, without fully understanding the subject, question the price which to many water-works people seems a fair and just one. I had hoped that Mr. Jordan would be here in person, and give us some sidelights on the hydrant income question.

I would like to hear from some of the members present with reference to hydrant charges, whether they consider it fair and equitable for cities to pay nothing for hydrants, thus compelling the water takers to assume the expense of hydrant protection, or whether the municipality should not pay a fair sum for hydrants.

Mr. Tighe stated that the hydrant rental in Holyoke was eight dollars each per annum, and that such charge covered the total cost.

Mr. James L. Tighe.† In the city of Holyoke the municipal water works not only maintains itself, but also pays a tax to the city, as if it were a private corporation. It does all this on an

* Superintendent Pennichuck Water Works, Nashua, N. H.
† Engineer Water Works, Holyoke, Mass.

income which is somewhat less than eight per cent. of the physical value or actual cost of the construction of the works.

In return for the payment of this tax, the water department collects from the municipality payment for all the water which the municipality uses at the same prices as are charged private consumers.

Many people argue that this tax that is placed upon the water department or water taker is an unjust one, but, so far as I can see, it is an eminently just and equitable one, because the water department has certain privileges from the municipality which it should be willing to pay something for. It has, for instance, a valuable franchise that permits it to tear up and lay pipes through the streets. It has also police protection for nothing, and, last but not least, it has the credit of the city behind it which enables it not only to borrow money, but to borrow it at a low rate of interest.

Now, are these privileges not worth something, and is it not just or equitable that the water taker should pay something for them?

Mr. Metcalf mentioned that $18.00 is a fair amount to charge for water per year per family. In Holyoke we charge for water the net sum of $6.66 per year per family. This does not include the lawn hose, which is $2.14 extra per year. It includes, however, all the modern fixtures and conveniences installed.

Holyoke is a very sanitary city, and, in order to encourage sanitation as much as possible, nothing is charged to families for duplicate fixtures such as bath-tubs, closets, faucets, or wash basins, no matter how many are installed.

Our water rates were cut down over thirteen thousand dollars last year, which makes the rates now in Holyoke about the lowest in any city in the country; that is, the lowest for a plant that maintains itself, or more especially for a plant that maintains itself and contributes between one fifth and one sixth of its income in taxes to the general taxation fund of the municipality.

In relation to metered water used for mechanical and manufacturing purposes, there is charged for this the net flat rate of 5.1 cents per 1 000 gallons, together with an annual charge for the meter of from 10 to 12 per cent. of its cost price. I do not think

that this price for metered water can be beaten very much anywhere.

There is also a metered rate for what is called tenement or apartment blocks containing four or more tenements. This metered rate was made especially for this class of property in order to discourage waste, and does not apply to residences because those living in the latter do not favor meters or want to be bothered with them, or with the meter men coming around once a month to read them, even though such would cut down the bills, and why should they so long as the schedule rates give them all the water they need, and especially all they can waste, for the small sum of $6.66 per year.

The minimum net rate for the tenement or apartment block is fixed at $4.50 per year per tenement. This amount has to be paid, together with the 10 or 12 per cent. interest on the first cost of the meter, no matter now little the quantity of water used. For this amount of $4.50, each family is allowed 88 000 gallons per year, which is almost 50 gallons per capita per day, assuming a family of five to each tenement. Should a larger quantity than 88 000 gallons per year — or 22 000 gallons per quarter — be used, it is charged for at the usual flat rate of 5.1 cents per 1 000 gallons.

This meter rate per tenement for the average tenement or apartment block, namely, an eight-tenement block, gives a minimum cost of $4.75, or a cost 29 per cent. less than the schedule rate per tenement.

In Holyoke, pipe lines are laid and extended in streets to accommodate all buildings, even if there be but one house on a street.

I was thinking, when Mr. Metcalf and Mr. Hawley were speaking in relation to pipe extensions in the outlying districts of a community, from which little returns could be expected for years, of asking the question as to what about the returns that are received from the thickly populated centers of the community. Should not these offset those from the outlying districts, or both go together?

The charge for hydrant service in Holyoke is $8.00 per hydrant, which includes all the water used for fire purposes. This charge is based only on the actual cost of setting and maintaining the

hydrant, and on the interest on the first cost of the hydrant itself.

The cost to the water taker of the larger pipe required for fire service beyond that required for domestic services only is considered offset by the valuable privileges which the water taker enjoys under the protection of the city. This is Municipal Ownership.

Mr. Arthur A. Reimer. I would like to ask if the water department has to meet the sinking fund requirements for its bonded indebtedness.

Mr. Tighe. Yes; the water department meets and has always met these requirements, and the taxpayer never had to pay a cent as yet for or towards the water department. I would say, however, that in 1876 or 1877, or shortly after the water works became a municipal department, a sum of ten thousand dollars of the taxpayers' money was voted or appropriated by the city council to the water department, to pay for doing some work.

In 1900 this generosity of the city fathers was resurrected, and the result was that the water department had to pay back this ten thousand dollars together with interest at four per cent. What came near to being the best of the joke, on the water department, however, was the argument made that compound interest should be paid, and it was only the law of Massachusetts, which does not allow compound interest to be collected on debts, that prevented it.

Mr. Leonard Metcalf. I would like to ask Mr. Tighe one thing, — whether it is not true that a considerable portion of the water debt has been paid off, so that the interest charges to-day are not predicated upon the value of the works to-day, but upon the outstanding bonds, — that is, the unpaid debt.

Mr. Tighe. I will answer the question by stating that the bonded debt is now greater than it ever was before. When the original bonds were paid off, new ones had been issued which increased the debt fifty thousand dollars.

Mr. Metcalf. I raised that point, Mr. President, for the reason that it would make a great difference whether a portion of the bonded debt had been paid off or not. Take it in my own little town of Concord, Mass.; the construction cost of the works now

amounts, without the improvements which were made last year or the year before, to something like two hundred and fifty thousand dollars. It is now somewhat greater. But I think the remaining debt was only something like ten or fifteen thousand dollars, so that there were no fixed charges to be met, to speak of. Of course the rates under those circumstances could be cut very substantially, it being apparent that the consumer had been taxed in the past years a sufficient amount to give a sinking fund which would retire the bonds in a comparatively short time. Now additional construction has been undertaken which has increased the debt, I think, something like twenty-five thousand dollars, which the consumer will have to bear; and in our town the sewerage works are maintained from the income of the water works, so that you could not compare the rates existing in Concord with those of any other town unless you made correction for a similar set of conditions.

Mr. Sullivan. In order to get the matter clearly in my mind, I would like to ask Mr. Tighe what the total cost of his works was, and also what the amount of bonds now outstanding is, and whether they are paying interest just on the present amount of bonds or on the total cost of the works.

Mr. Tighe. We are paying interest on the bonds now outstanding. We are not, of course, paying interest on the bonds that have been paid off.

Mr. Sullivan. What was the cost of the works, and what is the amount of bonds at the present time?

Mr. Tighe. I think the construction account is about a million and a half, and the first issue of bonds was $300 000 and the present issue is $350 000. We are now going to make another issue of $150 000 in order to raise money to pay for the construction of a new reservoir.

Mr. Metcalf. So you are paying on a total bond issue of how much?

Mr. Tighe. We are paying on a total bond issue of $350 000 at the present time.

Mr. Metcalf. That is the very question which I raised. You are paying, then, not upon the value of the works, but merely upon the remaining outstanding debt?

Mr. Tighe. Yes, upon the outstanding debt.

Mr. Metcalf. But upon a debt which has been cut down by excessive rates?

Mr. Tighe. No, but upon a debt that has been increased fifty thousand dollars. Our rates had never been excessive and were never within 70 per cent. of being as high as the rate of $18.00 mentioned above.

Mr. Sullivan. Do I understand the final answer to be that you are now paying on $300 000 of bonds and have a $1 500 000 investment from which there is no interest being received?

Mr. Tighe. Yes. I might say that this interest is paid in dividends to the water takers in the form of cheaper water rates from time to time. Every decade or so, a reduction in the water rates has been made, which means a dividend to the water takers. For instance, last year the water takers got a dividend of $13 000, or they had to pay $13 000 less for water, which is the same thing.

The tax that the water department pays is based on the construction account. This tax amounted to over $22 000 last year, and was based on a value of a little over $1 500 000. It was not based upon the value of the outstanding bonds, but upon the total construction account of the works the same as if the works belonged to a private corporation.

The President. I understood you to say, Mr. Tighe, that you earned seven or eight per cent. on your construction account; is that on the total cost of the works to date, or on your bonded debt?

Mr. Tighe. On the total cost of construction to date. I think there is a little over one hundred thousand dollars of income, and the cost of the works is about a million and a half; that is, the construction account amounts to that.

Mr. Metcalf. I wonder if Mr. Tighe would be good enough to throw a little more light on the matter of the hydrant rental. I am surprised at his statement that they estimate that the cost of the hydrant service is so low as $8.00 per hydrant. I know we looked into this question in connection with the Finance Commission investigation in Boston, and we found that it exceeded that amount very largely, and in the cases of private works which I have examined, the cost has always exceeded that amount very largely. I am surprised that the total cost of the hydrant service

should not be more than $8.00, which I understand him to state in his estimate.

Mr. Tighe. I had advocated that it should be $10.00, but it was made $8.00. This means the interest on actual cost of the hydrant only, the setting of it, and its maintenance.

Mr. Metcalf. Regardless of the additional cost of the pipe system?

Mr. Tighe. Certainly, regardless of the additional cost of the pipe system. In the discussion of the matter at the time between the representatives of the water department and the city proper, it was agreed that for the valuable privileges which the water taker enjoyed under the city, — that is, in being allowed to lay pipes through the streets and so on, police protection, and the credit of the city at his back, — the water taker ought, at least, to pay in return for the extra size of the pipe required for fire protection.

Mr. Theodore H. McKenzie. May I ask Mr. Tighe what he has done in Holyoke with reference to a sinking fund to provide for the renewal of the works. Ordinarily the depreciation on water works amounts to from three to five per cent. per annum, and I was wondering what they did about providing for reconstruction.

Mr. Tighe. We, of course, provide a sinking fund for the payment of bonds. Beyond this we do not make any provision because the creation and building up of a fund by one branch of a municipality in anticipation of future expenditures is a dangerous procedure unless such is protected by law.

It has been found, I think, where such has been attempted, that after a while, when the fund became any sizable amount, it was raided or wholly confiscated by the legislative body of the municipality and used for the more pressing needs of meeting the deficits in some of the other departments of the municipality.

In regard to renewals, I may say that these, together with extensions, are paid for out of the earnings of the department. For instance, this present year, and in the past two years, several thousand feet of 4-in. pipe, which was laid in the early days, have been replaced by new cast-iron pipe from 8 in. to 16 in. in diameter. So you see that the plant, instead of being allowed to depreciate,

is, on the contrary, being brought to a higher state of efficiency every year.

Mr. William Murdoch.* I might say in a general way that we have no hydrant rental at all in the St. John water works, but a hydrant tax; that is, we assess the whole community according to the individual wealth. We take that method of letting the people know that they own the water works.

We have one schedule rate for supply and another schedule of taxation of values amounting to from one fourth to one fifth of one per cent. of the assessors' valuation, so that the assessment which we collect every year covers hydrant rentals and some other public services. As the city can't tax itself on values, we charge only the regular consumption rate on the city properties, such as ferries and public buildings, including the fire department buildings.

The cost of our works and plant, up to the present time, has been $2 071 070.79. The expenditure during last year was $156 053.42 and the income $181 868.67. Of the outgo, $22 394.00 went into sinking fund to retire debentures and $89 326.07 was paid in interest upon debentures, which varies from 3½ to 6 per cent.

The water department is a separate department from the assessment department and is what remains of what was originally a water company. It is a department of the city service, and it maintains its identity and assesses the citizens for the service. It is a self-sustaining department, and any money that remains over at the end of the year is placed in the sinking fund to redeem the bonds. I think our bond issues are very much like those the previous speaker has spoken of. When the time comes for them to be paid, we sometimes issue a new set and keep things alive in that way.

We have about 55 miles of distribution mains, varying in diameter from 1½ in. to 36 in., 420 fire hydrants, and 35 miles of service pipes supplying about 47 000 inhabitants.

The supply comes from two distinct sources, about 16 miles apart. This is in consequence of the city being in two parts, one on each side of the River Saint John, the depth of which is fully one hundred feet. A 12- and a 24-in. pipe supply the West Side, where the population is about 8 000, and the East Side is served through one 12- and two 24-in. mains.

* City Engineer, St. John, N. B.

PROCEEDINGS.

The Twenty-Ninth Annual Convention.

Rochester, N. Y., September 21, 22, 23, 1910.

The Twenty-Ninth Annual Convention of the New England Water Works Association was held at Rochester, N. Y., September 21, 22, and 23, 1910.

The headquarters of the Association were at Hotel Seneca, where the several sessions of the convention were held and the exhibits of the Association made.

On Tuesday evening a reception was tendered to members and guests at the Hotel Seneca by the local committee.

The following members and guests were present:

Honorary Member.

F. W. Shepperd.

Members.

J. W. Ackerman, S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, F. D. Berry, C. R. Bettes, H. R. Cooper, G. K. Crandall, C. E. Davis, M. J. Doyle, E. R. Dyer, E. D. Eldridge, B. R. Felton, E. A. Fisher, J. W. Graham, F. E. Hall, L. P. Hapgood, L. M. Hastings, W. C. Hawley, Allen Hazen, George Holtzmann, W. R. Hill, W. C. Hopper, W. E. Johnson, J. W. Kay, Willard Kent, G. A. King, J. J. Kirkpatrick, Morris Knowles, Emil Kuichling, B. C. Little, F. H. Luce, Daniel McDonald, D. B. McCarthy, T. H. McKenzie, A. E. Martin, John Mayo, Leonard Metcalf, William Murdoch, F. L. Northrop, H. D. Pease, E. M. Peck, T. A. Pierce, A. E. Pickup, R. W. Pratt, J. F. Reagan, Jr., A. A. Reimer, Henry Roberts, G. A. Sanborn, P. R. Sanders, W. J. Sando, A. L. Sawyer, E. M. Shedd, J. E. Sheldon, G. H. Snell, J. F. Sprenkel, G. A. Stacy, G. T. Staples, W. F. Sullivan, D. G. Thomas, R. J. Thomas, J. L. Tighe, J. A. Tilden, J. G. Trautwine, Jr., J. H. Walsh, Hardolph Wasteneys, R. S. Weston, G. E. Winslow, I. S. Wood. — 72.

Associates.

American Asphaltum and Rubber Company, by Ray B. Nisbet; Anderson Coupling Company, by C. E. Pratt; Ashton Valve Company, by Columbus Dill and C. W. Houghton; Builders Iron Foundry, by A. B. Coulters; Chap-

man Valve Manufacturing Company, by H. L. DeWolfe, A. W. Hobbs, J. M. Noonan, A. W. Gilbert, and Thos. Rudley; Allyne Brass Foundry Company, by B. Thos. Beardsley, R. M. Corcoran, C. R. Bohn, and J. N. Frantz; Darling Pump and Manufacturing Company, by H. H. Davis and J. L. Hough; Gamon Meter Company, by C. A. Vaughan, W. H. Buckley, E. W. Gamon; George E. Gilchrist Company, by W. J. Chellew; Glauber Brass Manufacturing Company, by A. I. Fischer and Sam Davis; Hays Manufacturing Company, by C. E. Mueller, H. H. Clemens, and T. J. Nagle; Hersey Manufacturing Company, by L. S. Barnard, W. A. Hersey, W. C. Sherwood, Frank Whitlock, and J. A. Tilden; International Steam Pump Company, by Samuel Harison, D. A. Acer, A. Neidemeyer, and D. A. Decrow; Kennedy Valve Company, by M. J. Brosnan; Lead Lined Iron Pipe Company, by Thomas Dwyer and J. W. McCormack; Ludlow Valve Manufacturing Company, by T. A. Galvin and A. R. Taylor; Chas. Millar & Son Company, by C. F. Glavin; H. Mueller, Manufacturing Company, by G. A. Caldwell, R. M. Hastings, F. B. Mueller, O. B. Mueller, and T. G. Paradine; National Meter Company, by W. P. Oliver, J. G. Lufkin, John C. Kelley, Jr., and C. H. Baldwin; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by J. F. Reagan, Jr., F. A. Smith, T. D. Faulks, and H. H. Kinsey; New York Continental Jewell Filtration Company, by R. E. Milligan; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by J. M. Jones, V. E. Arnold, T. C. Clifford, and F. L. Northrop; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates, C. L. Brown, and J. S. Warde, Jr.; Ross Valve Manufacturing Company, by W. R. Ross and J. C. Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb and T. F. Halpin; Thomson Meter Company, by E. M. Shedd, W. S. Cetti, and S. D. Higley; Union Water Meter Company, by L. P. Anderson and F. E. Hall; U. S. Cast Iron Pipe and Foundry Company, by W. H. Franklin; Water Works Equipment Company, by W. H. Van Winkle and H. M. Heim; R. D. Wood & Co., by W. F. Woodburn and C. R. Wood; Standard Cast-Iron Pipe and Foundry Company, by W. E. Dodds. — 79.

GUESTS.

Mrs. E. M. Finigan and Miss B. Moran, Lyons, N. Y.; Mr. and Mrs. Pailsey, Mr. and Mrs. John F. Skinner, Frederick T. Elwood, Mrs. Beekman C. Little, H. S. Judson, George A. Beach, H. L. DeLaney, Thos. J. Neville, George H. Bliven, G. K. M. Clarke, Jos. E. Putnam, Ruden W. Post, Miss Mamie Miller, Mrs. George Miller, Mrs. George Cripps, David H. Westbury, Mr. and Mrs. John F. Amos, Mrs. E. A. Fisher, Miss Fanny B. Fisher, N. Adelbert Brown, F. L. Pease and Montgomery E. Leary, Rochester, N. Y.; John A. Hamilton, Paterson, N. J.; Mr. and Mrs. Alex Milne, St. Catherines, Ont.; Mrs. D. G. Thomas, Denver, Colo.; C. H. Ross, Waterloo, N. Y.; B. F. Sonder, Atlantic City, N. J.; Norman J. Gould, Seneca Falls, N. Y.; Frank Anigoni, Middletown, Conn.; Mr. and Mrs. W. Calahan, John H.

Shifferens, Mrs. A. Neidermeyer, Miss Neidermeyer, Henry L. Lyons, W. E. Glass, Edward A. Ritter, George M. Schmich and Mrs. Charles E. Richardson, Buffalo, N. Y.; Mrs. George Holtzmann, Schenectady, N. Y.; Ray Douglass, George R. Ellis, Canandaigua, N. Y.; Mrs. F. C. Luce, Woodhaven, N. Y.; Mrs. H. W. Hosford, Norwood, Mass.; C. J. Biladeau, J. F. Biladeau, Pittsfield, Mass.; Mrs. J. W. Kay, Milford, Mass.; John K. Gunn, Utica, N. Y.; C. P. Pollard, Jr., I. E. Stansbury, Baltimore, Md.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. T. J. Carmody, Miss Mary T. Ryan, Holyoke, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. George T. Staples, Dedham, Mass.; Mrs. R. J. Thomas, Lowell, Mass.; Mrs. John Mayo, Bridgewater, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. I. S. Wood, Providence, R. I.; Mrs. George A. Stacy, Marlboro, Mass.; Mrs. T. A. Pierce, Mrs. Emma A. Vaughan, East Providence, R. I.; Mrs. Columbus Dill, T. A. Collins, Miss J. M. Ham, Boston, Mass.; Mr. and Mrs. J. J. Desmond, Lawrence, Mass.; A. E. Kornfeld, I. S. Holbrook, E. T. Walker, J. M. Goodell, Mrs. F. W. Shepperd, New York City; D. C. Barrows, Olean, N. Y.; Mrs. J. C. Ross, Mrs. James M. Caird, Mrs. Fred S. Bates, Troy, N. Y.; Mr. and Mrs. A. W. P. Cobb, Auburn, Me.; Mr. and Mrs. J. B. Longley, Lewiston, Me.; C. A. Goodhue, Thompsonville, Conn.; Mr. and Mrs. James P. Bacon, Mrs. L. M. Hastings, Cambridge, Mass.; Joseph Alger, Brockton, Mass.; Mrs. L. P. Hapgood, Springfield, Mass.; Mrs. Ernest Gamon, Newark, N. J.; Mrs. Charles R. Wood, Philadelphia, Pa.; Henry V. Van Order, Ithaca, N. Y. — 95.

Total members and guests present, 246.
The following had exhibits:

MEMBERS.

Geo. T. Staples.
Geo. H. Snell.
Geo. E. Winslow.
E. R. Dyer.
A. S. Sawyer.
Frank E. Merrill.
H. B. Van Order.

ASSOCIATE.

H. Mueller Manufacturing Company.
Geo. E. Gilchrist Company.
Glauber Brass Manufacturing Company.
Union Water Meter Company.
Allyne Brass Foundry Company.
R. D. Wood & Co.
The Pitometer Company.

The Ashton Valve Company.
Hersey Manufacturing Company.
Neptune Meter Company.
American Ashphaltum and Rubber Company
The Gamon Meter Company.
Henry R. Worthington Company.
Alexander Milburn Company.
Chapman Valve Manufacturing Company.
National Water Main Cleaning Company.
Water Works Equipment Company.
Lead Lined Iron Pipe Company.
Thomson Meter Company.
Pittsburg Meter Company.
Ross Valve Manufacturing Company.
Hays Manufacturing Company.
Builders Iron Foundry.
National Water Meter Company.
A. P. Smith Manufacturing Company.
Norwood Engineering Company.

ROCHESTER INDUSTRIES.

Eastman Kodak Company.
Bausch & Lomb Optical Company.
Luitwieler Pumping Engineering Company.
Taylor Instrumental Companies.
Gleason Works.
Rochester Water Department.

FORENOON, WEDNESDAY, SEPTEMBER 21.

The convention was called to order at 10.30 A.M., by George A. King, President. His Honor Mayor Hiram Edgerton was presented, and made a short address of welcome, as follows.

Mr. President and Gentlemen of the New England Water Works Association, — The city of Rochester cordially welcomes all visitors, and it has been my privilege upon many occasions to extend the greetings of my fellow-citizens to gatherings of this character. We feel honored in having with us so many distinguished people as are connected with this organization. Our invitation and our welcome is not, however, entirely unselfish, for we expect to learn from you many things which will be of benefit to us. In return, we are willing to give you the best we

have. We have a beautiful city, and we are very proud of it. We are glad to have you here at a time when we can show the city to you under such favorable circumstances. We trust that your visit among us will be not only pleasant but profitable, and that you will receive such impressions as will cause you to remember us with pleasure and wish to come back again. We give you a most cordial welcome, and, so far as is possible, we extend to you also the freedom of the city, to go where you will, when you will, — and we know you will be welcomed everywhere.

The President. Mr. Mayor, I thank you for your words of welcome, and we shall be pleased to accept your courtesies. We have with us another representative of the city of Rochester, the secretary of the Chamber of Commerce, Mr. Roland B. Woodward.

Mr. Woodward. *Mr. President and Gentlemen,* — My experience with water-works conventions is limited, but very vivid. I went to Milwaukee to a meeting of the American Water Works Association, and if I ever saw a gathering which belied its name, that one did. I didn't recover from the effects of my attendance in time to go to the last meeting at New Orleans. They are coming to Rochester next year, as you know, and we will show them the finest system of water works that they have ever seen, although they can dilute the water if they want to.

But everybody who comes to Rochester has a good time, and we don't want you people to be any exception to the rule. There is something about the atmosphere of this city that is exhilarating, and after you have been here two or three days we hope you will feel just like old-time Rochesterians. That is the spirit of our city: A spirit of open-hearted and open-handed hospitality, and we are glad to have you here. The mayor has tendered you a welcome in behalf of the city, and I take pleasure in welcoming you in behalf of the business interests of the city, which I represent through the Chamber of Commerce. Our invitations have gone to different organizations, and we have welcomed here the Jew and Gentile, the Catholic and the Protestant, representatives of business interests at home and abroad, — in fact, we have had among us all types and kinds of men, and we have yet to hear of any gathering in this city that has not received fair and courteous treatment. We know that you will have a good time, and we know

that we will leave nothing undone which will help you to have a good time. We are proud of our city, we are proud of the people who visit us, and we want them to go away feeling that this is a fine city in which to visit or in which to live. We hope that some of you will find this place so attractive that you can appreciate the feelings of one man who, after having spent a few days here, said : "It has always worried me somewhat as to where I should go if I died and couldn't get into heaven, but now my mind is at rest. If I went up there and applied for admission and St. Peter said, 'No, you can't come in,' I should simply say, 'All right, never mind; I will just go back to Rochester.'"

After thanking Mr. Woodward for his words of welcome, the President called upon the Secretary, who read the following names of applicants for membership, properly endorsed and recommended by the Executive Committee:

Active: Joseph F. Biladeau, Pittsfield, Mass., superintendent; Chester Gordon Gillespie, Berkeley, Cal., engaged in the designing and operation of water filtration plants; Richard R. Bradbury, West Shokan, N. Y., section engineer, Board of Water Supply, New York City; Charles Henry Preston, Jr., Waterbury Conn., civil engineer; William E. Hannon, Boston, Mass., water commissioner; Leslie O. Smith, Columbus, Ohio, engaged in physical and auditing examination and superintending of water works; George R. Ellis, Canandaigua, N. Y., superintendent of water department; Henry B. Van Order, Ithaca, N. Y., superintendent of meters; George L. Weller, Elyria, Ohio, superintendent water works. — 9.

Associate: Allyne Brass Foundry Company, Detroit, Mich.; Standard Cast-Iron Pipe and Foundry Company, Bristol, Pa.; Kickerbocker Engineering Company, Brooklyn, N. Y. — 3.

On motion of Lewis M. Bancroft, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so they were declared by the President to be duly elected members of the Association.

On motion of Mr. James L. Tighe, it was voted that the President be authorized to appoint a committee of five to nominate officers for the ensuing year, and the President appointed as the committee, James L. Tighe, M. N. Baker, R. S. Weston, J. C. Hammond, Jr., and R. C. P. Coggeshall.

THE PRESIDENT. Some two months ago I was asked, as President of the Association, to appoint delegates to attend the Second National Conservation Congress at St. Paul, and I appointed as our delegates Mr. J. F. Fanning, of Minneapolis; J. W. Alvord, of Chicago; G. H. Benzenberg, of Milwaukee; D. W. Meade, of Madison; and J. Robert Adams, of St. Paul. These gentlemen all accepted the appointment, and I have received the following letter from Mr. Benzenberg.

MILWAUKEE, September 12, 1910.

Mr. GEO. A. KING, *Prest. N. E. W. W. Assoc.*,
TAUNTON, MASS.

Dear Sir,—I wish to report that I attended the Second National Conservation Congress at St. Paul last week, together with Professor D. W. Meade. I did not have the pleasure of meeting the other delegates appointed by you.

Enclosed I send you a copy of the program for the week. Comparatively little was accomplished by the congress, most of the time being taken up by the speakers on the question of state rights versus the right of the federal government to develop and control the natural resources, and by addresses. Aside from that by the president and that by Mr. Roosevelt, — which may be useful for political purposes, — very little of a really practical nature was submitted. The representatives of technical societies did not constitute a factor of the congress. I will send you or the Secretary, as you may direct, a complete copy of all the proceedings of the congress as soon as the same are printed and bound, which will be in about three months from now.

Hoping you will have a very successful meeting at Rochester, I remain,

Very truly yours,
G. H. BENZENBERG.

I directed Mr. Benzenberg to send his copy of the proceedings to our headquarters at Boston, and if any of you wish to consult the volume at any time you will find it there after it is issued.

MR. GEORGE A. STACY. *Mr. President,* — I desire to make a motion at this time in regard to a kindred association. I move that the Secretary be instructed to send this telegram: "The New England Water Works Association, in convention assembled at Rochester, N. Y., September 21, 1910, to the Central Water Works Association assembled at its thirteenth annual convention, sends greetings and congratulations." [Adopted.]

The President announced that the Executive Committee had considered somewhat the matter of the place for the next annual

convention, and had appointed a subcommittee consisting of the President, the Secretary, and Mr. Allen Hazen, to look into the subject. The committee would be pleased to receive suggestions at any time.

Evening.

The following papers were read at the evening session:

"A General Description of Rochester, Its Municipal Government and Physical Features," by Mr. Edwin A. Fisher, city engineer, Rochester, N. Y.; "Pertinent Matters relating to Water Works," by Mr. Frederick T. Elwood, commissioner of public works, Rochester, N. Y.; "A Description of the Rochester Water Works," by Mr. Beekman C. Little, superintendent of water works, Rochester, N. Y.; "New Reservoir at Cobb's Hill" (illustrated), by Mr. John F. Skinner, principal assistant engineer, Rochester, N. Y.

An address was then made by Mr. R. N. Searles, vice-president of the Chamber of Commerce, upon the "Rochester Spirit."

Mr. C. C. Laney, superintendent of parks, Rochester, N. Y., gave a brief description of the Rochester park system, and showed a number of stereopticon views of scenes in the various parks.

[Adjourned to 10 A.M., Thursday, September 22.]

Thursday Morning, September 22.

The Secretary read the following telegram received from the Central States Water Works Association: "We acknowledge with grateful appreciation receipt of your telegram of kind greetings. The Central States Water Works Association return to your assembly now in session at Rochester, N. Y., their cordial greetings, and wish you the fullest measure of success in your good work."

Mr. Emil Kuichling, consulting engineer, New York, read a paper on "Steel Pipe Lines." The paper was discussed by Mr. Francis H. Luce, Mr. Edwin A. Fisher, Mr. William Murdock, Mr. Leonard Metcalf, Mr. L. M. Hastings, Mr. W. C. Hawley, Mr. Allen Hazen, Mr. Morris Knowles, and Mr. Robert S. Weston.

In the absence of Mr. F. C. Jordan, secretary of the Indianapolis Water Company, Indianapolis, Ind., who was in attendance

at the convention of the Central States Water Works Association, Mr. Leonard Metcalf read Mr. Jordan's paper on "Statistics of Growth of Income." The paper was discussed by Mr. Metcalf, Mr. W. C. Hawley, Mr. William F. Sullivan, Mr. James L. Tighe, Mr. Arthur A. Reimer, Mr. Theodore H. McKenzie, and Mr. William Murdock.

Afternoon.

Mr. William F. Woodburn, chairman of the Committee on Exhibits, made the following report.

"We have 26 exhibits from the associate members, 8 exhibits from the active members, and 5 exhibits from city of Rochester industries. The exhibits of the active members and of the city of Rochester industries have added a great deal of interest to the general exhibition. This has been a new feature this year, and it will undoubtedly be continued in the future. The associate members have given us a very nice line of exhibits. I wish to say that the local committee have been very kind. They attended to all the trucking and unpacking, so that the exhibitors have had very little bother. We are particularly indebted to the Rochester Water Department for these courtesies, and we thank them for it."

On motion of Mr. Reimer, it was voted that the report be accepted and placed on the minutes. The President, in discharging the committee, extended the thanks of the Association for its efficient service in providing one of the most interesting exhibitions the Association has ever had.

Mr. Leonard Metcalf, consulting engineer, Boston, Mass., then read a paper on "Depreciation in Water Works and Methods of Accounting Therefor." This paper was discussed by Mr. Arthur A. Reimer, Mr. Theodore H. McKenzie, Mr. James L. Tighe, Mr. Edward S. Cole, Mr. William S. Sullivan, Mr. Emil Kuichling, and the President.

Mr. Robert Spurr Weston, sanitary expert, Boston, Mass., read a paper on "Corrosion of Metals." At the conclusion of the reading of the paper by Mr. Weston, the President said:

"Some three months ago, in conversation with one of our members, Mr. Allen Hazen, in New York, he said he hoped that we might hear something at our convention about the effect of

hypochlorite of lime upon pipe, and suggested that some experiments had been made in New York, and that by writing to Mr. Wiggin I might obtain a contribution to the discussion of that subject. I received this noon the following letter:

New York, September 21, 1910.

Mr. George A. King, *President New England Water Works Association*, Rochester, N. Y.

Dear Sir, — Complying with your request to Mr. Wiggin, which he has referred to me, to take part in the discussion of Mr. Weston's paper on "Corrosion of Metals," I take pleasure in sending you herewith a statement of what data we have gathered regarding the effects of hypochlorite of lime on metals.

Yours truly,

HAROLD C. STEVENS.

Mr. Stevens's paper was read by Mr. James L. Tighe, and both papers were then discussed by Mr. Edward D. Eldredge, Mr. Samuel A. Agnew, Mr. Weston, Mr. W. G. Hawley, and Mr. William F. Sullivan.

Evening.

The following-named applicants were elected to membership, the Secretary casting the ballot of the Association: John M. Goodell, of New York, editor *Engineering Record*, active; The Gould Manufacturing Company, Seneca Falls, N. Y., associate.

Mr. Morris Knowles, chief engineer, Bureau of Filtration, Pittsburg, Pa., read a paper entitled, "The Use of the Water Ejector for Transporting Sand." Mr. Chester F. Drake, superintendent of filtration, Pittsburg, contributed a paper upon the same subject, which was read by Mr. W. C. Hawley. The subject was discussed by Mr. M. F. Collins and Mr. Allen Hazen.

At the conclusion of the discussion, the President announced that Mr. William F. Sullivan had a motion to make. Mr. Sullivan said:

"*Mr. President*, it seems to me that the committee whose duty it was to select a meeting place for this convention certainly made no mistake in selecting the city of Rochester, and I believe I express the feelings of the Association when I say that the people of Rochester have surely done their part to make our visit here pleasant and profitable.

"I therefore move that a rising vote of thanks be extended to the officials of the water department, to the city engineer, to the Chamber of Commerce, and to all who have in any way contributed to our instruction, entertainment, and pleasure; and that the Secretary of the Association be instructed to send to the proper persons an expression of our appreciation of the generous hospitality which has been shown us." [Adopted.]

Dr. Herbert D. Pease, sanitary expert, Board of Water Supply, New York City, gave a talk on "The Relation of Flies to the Transmission of Infectious Diseases." His address was illustrated by stereopticon views.

A paper by Professor H. T. Barnes, director of physics, McGill University, Montreal, Canada, on "Ice Formation," was read by title.

Mr. James M. Caird, chemist and bacteriologist, Troy, N. Y., read a paper on "The Purification Plant of the Rochester and Lake Ontario Water Company, Rochester, N. Y." Dr. J. Roby, of Rochester, Mr. W. C. Hawley, Mr. Emil Kuichling, and Mr. Leonard Metcalf contributed to the discussion. [Adjourned.]

November Meeting.

Hotel Brunswick,
Boston, November 9, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, C. A. Bogardus, G. A. P. Bucknam, G. A. Carpenter, George Cassell, J. C. Chase, J. H. Child, C. E. Childs, E. S. Cole, M. F. Collins, W. R. Conard, L. S. Doten, E. D. Eldredge, G. H. Finneran, J. H. Flynn, A. N. French, C. W. Gilbert, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, J. O. Hall, W. E. Hannan, Allen Hazen, M. F. Hicks, F. M. Hutchinson, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. E. Lochridge, A. R. McCallum, W. A. McKenzie, N. A. McMillen, D. E. Makepeace, A. D. Marble, A. E. Martin, John Mayo, F. E. Merrill, Leonard Metcalf, E. E. Minor, William

Naylor, F. L. Northrop, O. E. Parks, T. A. Peirce, L. C. Robinson, M. J. Rosenau, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, J. E. Sheldon, G. H. Snell, G. A. Stacy, G. T. Staples, E. L. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, W. H. Vaughan, C. K. Walker, R. S. Weston, F. I. Winslow, G. E. Winslow, L. S. Wood. — 76.

Associates.

American Asphaltum and Rubber Company, by R. B. Nisbet; Ashton Valve Company, by C. W. Houghton; Harold L. Bond & Co., by H. L. Bond and G. S. Hedge; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould and A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Pennsylvania Cement Company, by G. M. Clukas; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd, United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Union Water Meter Company, by E. P. King and F. E. Hall; R. D. Wood & Co., by William Woodburn. — 27.

Guests.

C. O. Bent, Gardner, Mass.; Clifton A. Crocker, Stanford L. Haynes, Springfield, Mass.; Dr. John F. Cahill, A. Fleming, J. J. Desmond, Lawrence, Mass.; C. A. Moore, Westfield, Mass.; Henry E. Warren, Ashland, Mass.; E. J. Titcomb, Rochdale, Mass.; F. D. Flynn, Canal Zone; J. W. Stinson, Cambridge, Mass.; John Thompson, Dracut, Mass.; George T. Palmer, F. E. Lenene, Boston, Mass. — 14.

The Secretary presented the following names of applicants for membership, all of whom had been approved by the Executive Committee.

Active. — Channing Smith, Cherry Valley, Mass., chairman of Board of Water Commissioners, Cherry Valley and Rochdale Water District; E. J. Whitcomb, Rochdale, Mass., member of Board of Water Commissioners, Cherry Valley and Rochdale District; Wisner Martin, Cambridge, Mass., for eleven years principal assistant engineer, Department of Public Works, New York City, now engineer to the Joint Water Board of Abington and Rockland, Mass. — 3.

On motion of Mr. T. A. Peirce, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants above named, and he having done so, they were declared by the President duly elected to membership.

Dr. John C. Cahill, mayor of the city of Lawrence, then addressed the Association on water-works topics, with especial reference to the construction and work of the Lawrence filter.

Mr. Edward S. Cole, C.E., of New York, read a paper on the subject of "Water Consumption and Statistics relating Thereto." The discussion which followed was participated in by Mr. Leonard Metcalf, Mr. Elbert E. Lochridge, Mr. George A. Stacy, the President, Mr. George A. Carpenter, Mr. Frank C. Kimball, Mr. Johnson, Mr. Allen Hazen, Mr. Frank A. McInnes, Mr. Robert S. Weston, Mr. John C. Chase, Mr. Samuel A. Agnew, Mr. F. H. Hayes, Mr. William S. Sullivan, Mr. Walter H. Richards, Mr. George Cassell, Mr. Robert J. Thomas, Mr. John J. Kirkpatrick, and Mr. George E. Winslow.

Mr. Allen Hazen, consulting engineer, of New York, presented a paper in which he considered the subject of the reasonable thickness of the walls of pipes in order to afford requisite strength. Mr. Leonard Metcalf, the President, and Mr. Robert S. Weston spoke in connection with the paper.

Mr. A. E. Martin.* Mr. President, it seems to me that neither Mr. Hazen's paper nor Mr. Cole's paper, especially Mr. Hazen's, should be buried in our files without some further action being taken upon them. If our pipe specification tables are not what they should be, they certainly ought to be changed. I should like to inquire if our Committee on Pipe Specifications is still in existence, and if it is not, it seems to me it ought to be revived and this paper of Mr. Hazen's referred to it.

The President. I understand, Mr. Martin, that the Committee on Standard Specifications for Cast-Iron Pipe, of which Mr. Brackett is the chairman, is still in existence.

Mr. Martin. Then I will make this motion: That Mr. Hazen's paper be referred to the Committee on Standard Specifications for Cast-Iron Pipe for study and further report, unless Mr. Hazen has some objection to that.

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* Superintendent of Water Works, Springfield, Mass.

The motion was adopted.

Mr. John O. Hall. I think that the matter which Mr. Cole has presented is also one of very great importance, and one which lies at the root of the financial element which enters into the question of water distribution. I will therefore move that his paper be referred to a committee of three, to be appointed by the chair, and reported upon.

The motion was adopted, and the President appointed as such committee: Mr. Leonard Metcalf, Mr. Frank J. Gifford, and Mr. William F. Sullivan.

Adjourned.

December Meeting.

Hotel Brunswick,
Boston, December 14, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Honorary Member.

Frederic P. Stearns.

Members.

E. R. B. Allardice, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, James Burnie, G. A. Carpenter, J. C. Chase, R. D. Chase, C. E. Childs, R. C. P. Coggeshall, M. F. Collins, A. W. Cuddeback, J. C. DeMello, Jr., John Doyle, E. D. Eldredge, J. H. Flynn, A. N. French, F. L. Fuller, A. S. Glover, F. H. Gunther, F. E. Hall, T. G. Hazard, Jr., H. R. Johnson, W. S. Johnson, F. T. Kemble, Willard Kent, Patrick Kieran, S. E. Killam, F. C. Kimball, G. A. Kimball, G. A. King, C. F. Knowlton, A. R. McCallum, F. A. McInnes, N. A. McMillen, D. E. Makepeace, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, William Naylor, F. L. Northrop, O. E. Parks, E. M. Peck, T. A. Peirce, H. E. Perry, W. D. Pollard, Dwight Porter, Henry Roberts, L. C. Robinson, H. E. Royce, A. L. Sawyer, W. H. Sears, E. M. Shedd, G. H. Snell, G. A. Stacy, T. V. Sullivan, W. F. Sullivan, G. T. Swarts, H. A. Symonds, L. A. Taylor, R. J. Thomas, L. D. Thorpe, E. J. Titcomb, D. N. Tower, C. H. Tuttle, W. H. Vaughn, L. J. Wilber, F. B. Wilkins, F. I. Winslow, G. E. Winslow, I. S. Wood. — 78.

Associates.

Ashton Valve Company, by H. H. Ashton and C. W. Houghton; Harold L. Bond Company, by F. M. Bates; Chapman Valve Manufacturing Company, by H. L. DeWolfe; Darling Pump and Manufacturing Company, by H. H. Davis; Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; International Steam Pump Company, by Samuel Harrison and S. F. Nye; Lead-Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor and H. F. Gould; Chas. Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; New York Continental Jewell Filtration Company, by R. E. Milligan; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Waldo Bros., by H. E. Browne; R. D. Wood & Co., by W. F. Woodburn. — 26.

Guests.

Samuel F. Crompton, engineer, East Greenwich, R. I.; A. M. Dunbar, water commissioner, Hyde Park, Mass.; F. F. Strout, J. H. A. Currier, F. H. Fay, H. A. Hanscom, Louis K. Rourke, and C. F. Wentworth, Boston, Mass.; F. E. Strickland, Wm. E. Atwater, and John E. Boyle, Westfield, Mass.; J. J. Desmond, Lawrence, Mass.; Samuel H. Lea, state engineer, Pierre, So. Dak.; G. H. Pratt, chemist, Rhode Island State Board of Health, Providence, R. I.; Thomas S. O. Connell, water commissioner, Wakefield, Mass. — 15.

The Secretary presented applications for membership, properly endorsed and approved, from Herbert P. T. Matte, Southbridge, Mass., assistant superintendent engineer, Southbridge Water Supply Company, and J. W. Speller, Pittsburg, Pa., chief chemist and metallurgical engineer for the National Tube Company.

On motion of Mr. Peirce, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared by the President duly elected members.

Louis K. Rourke, superintendent of streets, Boston, Mass., gave an interesting talk, illustrated by stereopticon views, on the Panama Canal. Mr. John C. Chase, Mr. Frank L. Fuller, and Mr. Frederic P. Stearns spoke briefly of visits made by them to the work.

Mr. Robert E. Milligan, manager of the New York Continental Jewell Filtration Company, read a paper on "The Water Filtration Plant at Newport, R. I." He was followed by Dr. Gardner T. Swarts, secretary of the State Board of Health of Rhode Island, whose subject was "Some Difficulties in the Purification of Water Supplies." The discussion was participated in by Mr. Pratt, Mr. Harry W. Clark, Mr. Robert S. Weston, and Mr. Leonard Metcalf. Dr. Swarts and Mr. Milligan spoke in reply.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of Executive Committee of the New England Water Works Association at Hotel Seneca, Rochester, N. Y., Wednesday, September 21, at 9.30 P.M.

Present: President George A. King, Allen Hazen, Michael F. Collins, Irving S. Wood, George A. Stacy, L. M. Bancroft, Robert J. Thomas, and Willard Kent.

Voted: That the following-named members and associates who were dropped for non-payment of dues, having since settled the same, be, and hereby are, reinstated:

Members: Messrs. T. W. Lesage, G. C. Bunker, R. S. Lea, B. R. Felton, E. P. Whitten, J. W. DuB. Gould, C. H. Rollins, R. W. Pratt, T. D. L. Coffin, W. H. Humphreys, A. J. Taylor, B. B. Hodgman, E. A. Weimer, and H. A. Lord.

Associates: Hart Packing and Pitometer Company.

Voted: That the following-named applications for membership and associate membership be, and hereby are, recommended for admission:

For membership: Charles H. Preston, Jr., civil and consulting engineer, Waterbury, Conn.; William E. Hannan, water commissioner, Boston, Mass.; Joseph F. Biladeau, superintendent water works, Pittsfield, Mass.; George L. Weller, superintendent water works, Elyria, Ohio; Chester G. Gillespie, Berkeley, Cal.; Richard R. Bradbury, West Shokan, N. Y.; George R. Ellis, superintendent water department, Canandaigua, N. Y.; Leslie C. Smith, superintendent water works, Cleveland, Ohio; Henry B. Van Order, superintendent water works, Ithaca, N. Y. — 9.

For associate membership: Knickerbocker Engineering Company, New York City; Allyne Brass Foundry Company, Detroit, Mich.; and Standard Cast Iron Pipe and Foundry Company, Bristol, Pa. — 3.

The question of the location for the next annual convention was discussed, and it was voted that the President, Vice-President

Hazen, and Secretary Kent be, and hereby are, appointed a committee to recommend a place for holding the annual convention of 1911, any necessary expense incurred by the committee to be borne by the Association.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Seneca, Rochester, N. Y., September 22, 1910.

Present: President George A. King, Allen Hazen, Michael F. Collins, Leonard Metcalf, Irving S. Wood, George W. Batchelder, and Willard Kent.

The following applications were received and recommended for admission:

For membership: John M. Goodell, editor *Engineering Record*, New York City.

For associate membership: Gould Manufacturing Company, Seneca Falls, N. Y.

For reinstatement to membership: Mrs. E. M. Finigan, secretary Lyons Water Company, Lyons, N. Y.

Bill rendered Mr. Arthur T. Safford for extra copies of report of committee appointed to collect data relating to awards for water and water-power diversion was, by vote, rebated.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Brunswick, Boston, Mass., November 9, 1910, at 12 m.

Present: President George A. King, Allen Hazen, Richard K. Hale, Lewis M. Bancroft, George A. Stacy, Leonard Metcalf, Robert J. Thomas, Irving S. Wood, and Willard Kent.

Three applications were received and recommended for admis-

sion, namely, for membership: Wisner Martin, civil engineer, Cambridge, Mass.; Channing Smith, water commissioner, Cherry Valley, Mass.; E. J. Titcomb, water commissioner, Rochdale, Mass.

Voted: That the President be and hereby is authorized to appoint a committee to consider the needs of the library of the Association. The President appointed as that committee Messrs. Charles S. Sherman, Richard K. Hale, and George A. Sampson.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Brunswick, Boston, Mass., Wednesday, December 14, 1910, at 12 M.

Present: President George A. King and members Michael F. Collins, Leonard Metcalf, Irving S. Wood, George A. Stacy, George W. Batchelder, Willard Kent, Lewis M. Bancroft, and Robert J. Thomas.

Two applications were received and recommended for admission, namely:

For membership: F. N. Speller, chemist, Pittsburg, Pa., and Herbert P. T. Matte, assistant superintendent Southbridge Water Supply Company, Southbridge, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

BOOK REVIEWS.

Sewerage. The Designing, Construction, and Maintenance of Sewerage Systems. By A. Prescott Folwell, editor *Municipal Journal and Engineer*. Sixth edition, revised and enlarged. 8vo, x + 506 pages, 46 figures, and 12 plates. New York: John Wiley & Sons, 1910. Cloth, $3.00.

While this book was primarily intended for practicing engineers, it is admirably adapted to use as a text-book in engineering schools.

The book is divided into four parts, the first three, designing, construction, and maintenance, dealing more directly with the sewerage system, the fourth with sewage disposal.

Under " Designing," the author discusses different types of systems, the amount of sewage, rainfall and run-off data, with the necessary sizes of sewers and questions of flushing and ventilation. There is then a statement of the surveys, borings, etc., that are necessarily made before the actual design of the system can be carried out.

The author then discusses the detailed design of the system and preparation of plans, with many illustrations of existing works. This first part of the book closes with an excellent chapter on contracts, specifications, and estimates of costs, with notes on the question of assessments. It includes nearly one half of the book.

Part II, " Construction," deals with the necessary preliminary work, engineering and otherwise, giving lines and grades, the inspection and measurement of the work, closing with a long chapter on the details and methods of construction.

The third part, " Maintenance," is a brief statement of the work required to keep the system in proper running order, with the necessary flushing, cleaning, etc.

Part IV, " Sewage Disposal," has been practically rewritten. In it the author discusses disposal by dilution and the various methods of treatment in use at the present time, with numerous items of cost of work.

On reading this book one misses the lists of references so common in many technical books, and forming such a valuable part of them. It would also seem that, as the book will reach so many city engineers and municipal officials, the author might have given valuable advice as to the keeping of statistics and the preparation of reports. Moreover, one is disappointed at finding so few figures of recent date. For instance, in Table 9, page 30, on maximum amounts of rainfall, there are no figures of storms later than 1896.

The book is well printed, the illustrations are numerous, though rather small, and there is a good index.

Sewage Disposal. By Leonard P. Kinnicutt, C.-E. A. Winslow, and R. Winthrop Pratt. 8vo, xxvi + 436 pages. 113 figures. New York: John Wiley & Sons, 1910. Cloth, $3.00 net.

In the preface the authors state that the book is intended to give a general survey of the problems of sewage disposal from the various viewpoints of the chemist, the sanitary biologist, and the engineer, and with particular attention to the conditions of American practice.

The intentions of the authors are well carried out and the book will be found to be of considerable value to students, engineers, and public officials interested in the design, construction, and operation of sewage disposal works.

In the introduction the authors discuss "the sanitary demand for sewerage and sewage disposal," covering briefly the dangers arising from accumulations of excreted material, the various systems of disposal, and their relations to the public health. The chemical composition of sewage is discussed in considerable detail.

The authors then discuss the various methods of treatment, under the headings of dilution, screening and straining, sedimentation, precipitation, septic process, disposal of sludge, broad irrigation and sewage farming, sand filtration, contact beds, trickling filters, sewage disinfection, and the methods of analyzing sewage and sewage effluents.

Under each of these headings there are numerous tables and diagrams showing the results obtained with the various methods of treatment. In many cases costs of the processes are stated.

There are numerous photographs and drawings of existing works and descriptions of the important features in considerable detail. There is a good bibliography.

The Corrosion of Iron and Steel; a Brief Treatise. By Alfred Lang. 130 pages, 5 x 8 inches. New York: The McGraw-Hill Book Company, 1910. Cloth, $1.00.

The author states in the preface that this essay is in a great measure a compilation and study of the results obtained by other investigators, and is intended as a compendium of the subject suitable for reference.

The book gives a brief statement of the various theories of rusting and corrosion, such as the carbonic acid theory, the hydrogen peroxide theory, and the electrolytic theory, and the effects of various gases and impurities.

One of the most valuable features of the book is the general bibliography of the more important articles on the corrosion of iron and steel.

MEMBERSHIP.

ADDITIONS.

(September 1 to December 1, 1910.)

MEMBERS.

Biladeau, Joseph F.
Superintendent Water Works, Pittsfield, Mass.

Bradley, Richard R.
Assistant Engineer, Board of Water Supply, New York City, West Shokan, N. Y.

Bridges, J. H.
Superintendent Henderson Water Company, Henderson, N. C.

Ellis, George R.
Superintendent Water Department, Canandaigua, N. Y.

Gillespie, Chester G.
1536 Walnut Street, Berkeley, Cal.

Goodell, John M.
239 West Thirty-ninth Street, New York City.

Hannan, William E.
Water Commissioner, Boston, Mass.

Preston, Charles H., Jr.
Civil and Consulting Engineer, 136 Grand Street, Waterbury, Conn.

Smith, Channing
Chairman Cherry Valley and Rochdale Water District, Cherry Valley, Mass.

Smith, Leslie C.
Superintendent Water Works, Cleveland, Ohio.

Titcomb, E. J.
Water Commissioner, Cherry Valley and Rochdale Water District, Rochdale, Mass.

Van Order, Henry B.
Superintendent Water Department, Ithaca, N. Y.

Weller, George L.
Superintendent Water Works, Elyria, N. Y.

Wisner, Martin
50 Highland Avenue, Cambridge, Mass.

ASSOCIATES.

Allyne Brass Foundry Company
Detroit, Mich.

Knickerbocker Engineering Company
21 Park Row, New York City.

Standard Cast Iron Pipe and Foundry Company
Bristol, Pa.

The Goulds Manufacturing Company
Seneca Falls, N. Y.

CHANGES OF ADDRESS.

MEMBERS.

Ayres, J. H.
Care City Engineer's Office, Manila, P. I.

Barnes, T. Howard
Puerto Barnos, Guatemala.

Barnes, William T.
Las Vegas, Mexico.

Bartlett, Charles H.
852 Elm Street, Manchester, N. H., and 60 Pemberton Square, Boston, Mass.

Beardsley, Joseph C.
Card Building, Cleveland, Ohio.

Bemis, Edward W.
106 Hamilton Avenue, New Brighton, Staten Island, N. Y.

Crowley, Robert J.
Member Lowell Water Board, 53 Central Street, Lowell, Mass.

Cutting, George W., Jr.
Care of Construction Quartermaster, Fort Mills, Corregidor, P. I.

Gregory, John H.
Engineer Metropolitan Sewerage Commission, 17 Battery Place, New York City.

Howard, John L.
Engineer's Office, City Hall, Pittsfield, Mass.

King, Arthur C.
43 Jefferson Avenue, Springfield, Mass.

Macksey, Henry V.
11 Gaylord Street, Dorchester, Mass.

Merrill, Andrew S.
414 Pleasant Street, Malden, Mass.

Miller, Hiram A.
14 Beacon Street, Room 507, Boston, Mass.

Miller, Stanley A.
1800 Monroe Street, Paducah, Ky.

Minor, Edward E.
Superintendent New Haven Water Company, 91 Temple Street, New Haven, Conn.

Norcross, Theodore W.
District Engineer, Forest Service, Majestic Building, Denver, Colo.

Perkins, John H.
Antrim, N. H.

Sando, Will J.
Care of Milwaukee Club, Milwaukee, Wis.

Tarbett, Ralph E.
Aspinwall, Pa.

Walden, A. E.
Superintendent and Chief Engineer, Baltimore County Water and Electric Company, 100–102 West Fayette Street, Baltimore, Md.

Warde, Charles S.
Department Water Supply, Gas and Electricity, Borough of Richmond, New Brighton, N. Y.

Wehr, Albert H.
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